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MBA PROFESSIONAL REPORT

The Role of the Department of Defense (DoD) in Solar Energy Research, Development and Diffusion

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June 2008

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The DoD uses approximately 1.8 percent of the oil consumed each day in the U.S. and is the largest single institutional energy customer in the United States. Additionally, the U.S. has the highest per capita oil consumption rate in the world. Mindful of America's growing dependence on foreign oil and the geopolitical forces that threaten world supplies and national security, DoD has vowed to convert to 25 percent renewable energy use by 2025. Through strategic partnerships with NGOs, commercial industry, and academia, DoD's unique organizational capacity makes it suited to not only reach this goal, but to serve as an example for a national transformation toward a new energy future. This report examines the feasibility of niche solar energy applications and the methods that DoD might positively impact solar energy research, development and technology diffusion.

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THE ROLE OF THE DEPARTMENT OF DEFENSE (DOD) IN SOLAR ENERGY RESEARCH, DEVELOPMENT AND DIFFUSION

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ABSTRACT

The DoD uses approximately 1.8 percent of the oil consumed each day in the U.S. and is the largest single institutional energy customer in the United States. Additionally, the U.S. has the highest per capita oil consumption rate in the world. Mindful of America's growing dependence on foreign oil and the geopolitical forces that threaten world supplies and national security, DoD has vowed to convert to 25 percent renewable energy use by 2025. Through strategic partnerships with NGOs, commercial industry, and academia, DoD's unique organizational capacity makes it suited to not only reach this goal, but to serve as an example for a national transformation toward a new energy future. This report examines the feasibility of niche solar energy applications and the methods that DoD might positively impact solar energy research, development and technology diffusion.

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I would like to thank my wife and my children for their support during this process. Without their support, I would not have been able to complete this report. I would also like to thank my partner Joe for all his hard work and 110% effort in making this project come together. I could not have completed this project by myself. Finally, I would like to thank Professor Dew for his support, guidance and expertise.

— LCDR William T. Benham Jr., SC, USN

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— LCDR Noel J. Cabral III, SC, USN

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I. INTRODUCTION

A. PREFACE

At the start of this research project, the price for light sweet crude oil was $95 per BBL. Four months later, it had soared to $134 per BBL (Energy Information Administration [EIA], 2008) with speculation of higher prices yet to come. During this short period, news media outlets were saturated with reports of looming recession, record gasoline prices, rising food prices, struggling citizens, permanent airline route closures, and many other undesirable effects. This is not the first time the world has experienced oil shocks, in fact during the past fifty years, there have been 14 significant oil supply disruptions, mostly related to political or military conflict in the Middle East (Geller, 2003). Reasons for rising price levels today are debated and disputed among industry experts and range from speculators driving prices, and oil companies hoarding profits, to turmoil and supply shortages in the Middle East and elsewhere. One particular argument that is pushing its way to the forefront that was not as hot an issue during previous oil shocks is that the world is rapidly approaching the inevitable peaking of oil production or has already surpassed it, depending on the source.

Global reserves fluctuate with the discovery of new oil fields and extraction technologies but sites that are easily discovered and have easy recovery are declining. This is leading to the condition that discoveries are decreasing over time while demand is increasing. The fact that 80 percent of today's oil reserves were discovered before 1973 supports this argument (U.S. Department of Energy [DOE], 2004). Also, according to DOE (2004) reserves are being depleted at three times the rate of discovery, and since 2000 the cost of finding and developing new oil sources has risen by fifteen percent annually (Lynch, 2005). This isn't to suggest that world reserves are running out in a few years, there is enough to last up to decades depending on how tolerant the market is to drilling deeper, in more inhospitable places, and for higher extraction and refining costs. With the issues of accessibility and the emergence of India and China, the literature suggests that the days of cheap accessible crude oil are now behind us, and this is the first time mankind has ever been faced with this new reality.

The implications of this new reality for America and the Department of Defense (DoD) are profound, especially since according to Lovins (2005), DoD is the largest single consumer of petroleum at 1.8 percent of total U.S. consumption. What Hornitschek (2006) contends however is that this figure does not even recognize indirect dependencies from military industrial supply, contractor support, commercial logistics, and installation requirements. Therefore, 1.8 percent may be a conservatively low estimate. An important question becomes, how can DoD contribute to creating a society which is less dependent on foreign oil while simultaneously maintaining the energy resources and capabilities to provide national security?

This report offers that DoD has the R&D capabilities, ability to create a sense of urgency, ability to form guiding coalitions, and political influence to secure it's own long term existence, and push society transformation along the renewable energy path to energy independence. The initial intent of this report was to champion solar energy projects as the best renewable energy source for DoD to focus efforts, however, research indicated that wind energy and geothermal energy have played a large role thus far in DoD's transformation and are still more cost effective than solar in most large scale applications. What was also realized however is that solar has been the best choice in many niche applications for DoD where wind and geothermal have been inappropriate or less cost effective. The number of implemented and future DoD niche solar applications has grown tremendously over the past 10 years and the scope of this report will center on the importance of purchasing and developing solar energy technology while not ignoring the merits of wind and geothermal.

B. PURPOSE

The purpose of the MBA professional report is to analyze the solar industry and the opportunities it might present for DoD to serve as an example for a national transformation toward a new energy future. It will also identify the economic and geological issues affecting conventional energy supply and demand, adoption of renewable energy, as well as the potential threats to national security should America continue on its current dependency of foreign-supplied fossil fuels.

C. SCOPE

This report focuses primarily on solar energy technology as a reliable energy alternative for DoD based on solar modular capability, cost, supply chain efficiency, global availability, and wide array of realized and potential applications. However, it is important to point out that any sound renewable energy strategy for DoD must comprise a portfolio of all the different renewable energy choices. The Energy Policy Act of 2005 specifically recognizes renewable energy as energy from "solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project" (Energy Policy Act, 2005).

DoD's focus has been on solar, wind and geothermal and leads all federal agencies by deriving approximately 10 percent of its energy from these renewable sources. This report discusses how DoD might become a leader in solar technology innovation, use, and diffusion through strategic partnerships, and strong actions to affect market supply and demand. The arguments presented may also be applied to other renewable energy choices. New energy technologies are beginning to make a difference today, and may make a bigger difference tomorrow.

D. METHODOLOGY

The methodology used in this research project consists of 4 components. First is a literature review of numerous books, scholarly journals, government reports, and other library resources to examine renewable energy and solar science, market and environmental characteristics of energy economies, and government and private activities in environmental and renewable energy programs. Next, are analyses of supply chains for solar energy and other energy sources, as well as financial realities facing DoD in the current campaigns in Iraq and Afghanistan as they relate to energy supply for military operations. The third component focuses on the nature of uncertainty in new technologies and how it impacts renewable energy development. Also covered is an analysis of technology learning and diffusion amid uncertainty and market barriers, and what actions DoD might take to drive diffusion of niche solar energy applications. The final component uses theories of networking and alliance building to successfully manage risk, build strategies for research and development, and diffuse technology through shared communication and synergistic partnerships.

E. SOLAR ENERGY TECHNOLOGY

The sun's heat and light provide an abundant source of energy that can be harnessed in many ways. There are a variety of technologies that have been developed to take advantage of solar energy. These include: solar thermal electricity, passive solar heating and day lighting, photovoltaic systems, and solar hot water.

1. Solar Thermal Electricity

Solar thermal energy (STE) systems use the sun's energy to superheat a fluid (normally water) and generate steam to drive a turbine and generator. The solar energy is concentrated either by a field of parabolic mirrors, dish-shaped collectors or large flat mirrors. STE systems have been around for two decades, successfully demonstrating capability in the California deserts using parabolic mirrors and steam turbines (Mills & Morgan, 2007). The newest STE option recently developed commercially is the Compact Linear Fresnel Reflector (CLFR) system which is a linear system using long steam pipe receivers on towers, illuminated by long flat mirrors (heliostats) below (Mills & Morgan, 2007). The appealing feature of STE is the low cost energy storage in artificial thermal reservoirs. This low cost water-based thermal storage is expected to be commercialized within two years (Mills & Morgan, 2007) and is more attractive than the limited battery storage options of photovoltaic systems.

2. Passive Solar Heating and Day-lighting

Passive solar systems take advantage of the fact that the south sides of buildings receive the most sunlight. Buildings designed for passive solar heating usually have large windows facing south (National Renewable Energy Laboratory [NREL], 2007). This system also takes advantage of the heat retention properties of certain materials by storing heat in floors and walls. For example, a Trombe wall is a thick south-facing wall, which is painted black and made of a heat absorbing material such as stone or metal. The wall absorbs heat during the daytime, and a glass or plastic glazing installed a few inches away limits the heat loss after sunset (NREL, 2006). A portion of the retained heat is transferred into the interior of the building, although most is lost to the outside.

A sunspace (which is much like a greenhouse) is also built on the south side of a building. As sunlight passes through glass or other glazing, it warms the sunspace. The heat captured is then ventilated throughout the building (NREL, 2006). Sunspaces are useful add-ons for buildings that were not originally designed for passive solar heating. Passive solar systems are also useful for day-lighting applications that allow sunlight to naturally brighten building interiors.

3. Photovoltaic Systems

Commonly known as solar cells, photovoltaic (PV) materials convert light energy into electrical energy and are commonly found in calculators, road signs, and satellites among other household and industrial applications. When sunlight is absorbed into the semiconducting materials, the solar energy knocks electrons loose from their atoms, creating electron flow and electricity (U.S. Department of Energy: Office of Energy Efficiency and Renewable Energy [EERE], 2006). PV cells come in many sizes and shapes, and forty cells (NREL, 2007) are often connected together to form PV modules that can be up to several feet long and a few feet wide. These modules are mounted in PV arrays of different sizes depending on desired power output.

These flat-plate PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. About 10 to 20 PV arrays can provide enough power for a typical household (NREL, 2007). Hundreds of arrays can be connected to form a single large PV system for large electric utility or industrial applications.

Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Thin film technology has made it possible for solar cells to now double as rooftop shingles, roof tiles, building facades, or the glazing for skylights or atria (EERE, 2006).

Discussed so far are flat PV arrays, however in order to cut down on the amount of expensive semiconductor materials used, some PV systems are designed to operate with concentrated sunlight. Photovoltaic cells are built into concentrating collectors that use a lens to focus the sunlight onto the cells, and require more sophisticated tracking devices.

The first solar cells, built in the 1950s, had efficiencies of less than 4 percent Technological advances since then have made typical commercial solar cells 15 percent efficient (NREL, 2007) but still, eighty-five percent of the sunlight that strikes a cell is reflected or absorbed by the material. Increasing this efficiency is still an important priority for NREL researchers and DOE laboratories.

4. Solar Hot Water

One of the most cost-effective ways to include renewable technologies into a building is by incorporating solar hot water. Typical water heating systems reduce the need for conventional water heating by about two-thirds, minimizing the expense of electricity or fossil fuels (EERE, 2006). Most solar water heating systems for buildings have two main parts; a solar collector and a storage tank. Flat-plate collectors are most common (NREL, 2006).

Solar water heaters use the sun to heat either water or a heat-transfer fluid like anti-freeze in the collector. The collector, mounted on the roof, consists of a thin, flat, rectangular box with a transparent cover that faces the sun. Small tubes run through the box and carry the fluid to be heated. The tubes are attached to an absorber plate, which is painted black to absorb the heat. As heat builds up in the collector, it heats the fluid passing through the tubes (NREL, 2006).

Heated water is then held in the storage tank ready for use, with a conventional system providing additional heating as necessary. The tank can be a modified standard water heater, but it's usually much larger and very well insulated.

Solar water heating systems can be either active or passive, but the most common are active systems. Active systems rely on pumps to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated (EERE, 2006).

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II. LITERATURE REVIEW

A. INTRODUCTION

In order to establish a strong fundamental understanding of renewable energy technology, policy, economics, and perceived energy challenges of the future, an extensive review of books, government reports, and academic journals was conducted. This chapter reviews the main body of literature consulted; what is common among all sources is the credibility and experience each author has earned from decades of insider knowledge, research, and experience. The authors of this literature have held varying high-level positions in the industry, including federal and state government energy policy positions, national energy councils and think tanks, oil company executive positions, and environmental agencies. Each has authored numerous books and articles on the subject of renewable energy, and is regarded as an expert in the field.

B. A THOUSAND BARRELS A SECOND: THE COMING OIL BREAK POINT AND THE CHALLENGES FACING AN ENERGY DEPENDENT WORLD — TERTZAKIAN

When President George W. Bush declared “America is addicted to oil” in a 2006 State of the Union Address, it seemed like a stunning remark from such an oil-friendly president, but, two years, later it is arguably an enormous understatement. With the ongoing crisis in the Middle East showing no end in sight and the unprecedented industrial growth of population giants India and China, it seems the world is likely on the cusp of an energy “breaking point” (Tertzakian, 2007). According to the literature, breaking points are crucial junctures marked by dramatic changes in the way energy is used. During a breakpoint and subsequent 10 to 20-year rebalancing, nations struggle for answers while frustrated consumers struggle and complain until the economy adapts as science surges with new innovation and discovery. The reality is that the world is not really running out of oil, just cheap oil. Most of the easily accessible “elephant” oil fields on the globe have already been discovered, but plenty of smaller pockets and remote large fields are still being found. The problem facing oil users is that new reserves are in geographically and politically inhospitable places. This, coupled with the rapid increase in demand for imported oil, is contributing to growing global risk and certainly United States national security risk.

1. Energy Cycle

To illustrate the concept of an energy breaking point, it is helpful to consider the energy cycle every economy experiences. Figure 1 shows four main stages of the cycle. Beginning with the top, every economy increases its energy demand as it grows, as a result, dependencies on a primary energy source form and take root, as a frenzy of new products and services flourish. Eventually, the primary energy source becomes scarce and pressure buildup begins. There are several forces that contribute to the pressure buildup. Geopolitical forces for example are undeniably important as scavengers hunt for the dwindling energy source. Environmental and social forces play an important role as pollution, deforestation, or species endangerment become forefront.

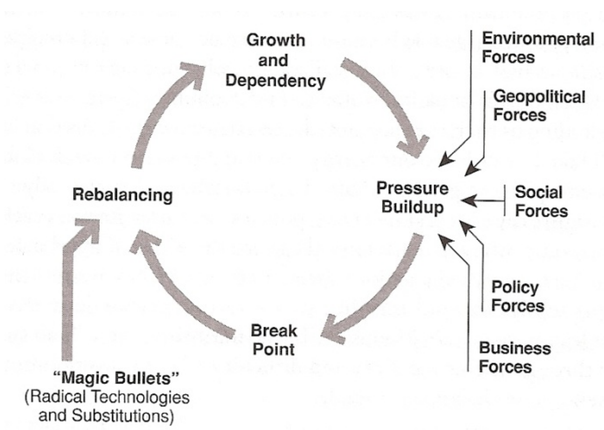

Figure 1. Energy Evolution Cycle [From: Tertzakian].

Eventually pressure leads to a break point where conservation, search for new sources, taxes, and incentives among other behaviors and actions drive the economy into rebalancing. Technologies emerge and substitutions ease the effects of the breakpoint and rebalance the economy. Tertzakian (2007) contends that all economies are locked into this cycle regardless of the primary energy source they are thriving on.

This model explains historical energy cycles and stands the test of time and history. One particular world energy transition to note is the transition away from whale oil, which was used for making candles and for illuminating lamps 150 years ago, as prices rose to shocking levels in response to dwindling whale count and increasingly remote harvesting locations. Eventually, the price shock was so unbearable for the world economy that a radical new technology emerged in 1849 (Tertzakian, 2007) that was cheaper and more desirable – kerosene. By the time the kerosene burner was invented in 1857 (Tertzakian, 2007), the whaling industry was dead.

The pressure buildup, break, and rebalancing of the oil energy market during the 1970s is a more recent testament to the lessons learned about energy source addiction. Triggered by the 1973 oil embargo by the Organization of Petroleum Exporting Countries (OPEC) and fed by global tension, drastic government action and consumer frustration, (Tertzakian, 2007) the world energy pressure rose and peaked. By the second oil shock of 1979 as a result of more turmoil and political upheaval in the middle east, oil prices rose to unbearable levels and action was required on the demand side as much as the supply side. Rebalancing occurred from 1980 to 1986 through conservation policies, fuel economy, and growth in coal, nuclear, natural gas, and renewables. The world emerged from the break point in 1986 looking much better off from an energy portfolio standpoint than in 1973 (Tertzakian, 2007). The United States energy balancing result depicted in Figure 2 below takes into account all end use markets (transportation and electricity generation) and extended energy stability modestly, but much more balanced portfolios emerged from such nations as Japan and the United Kingdom.

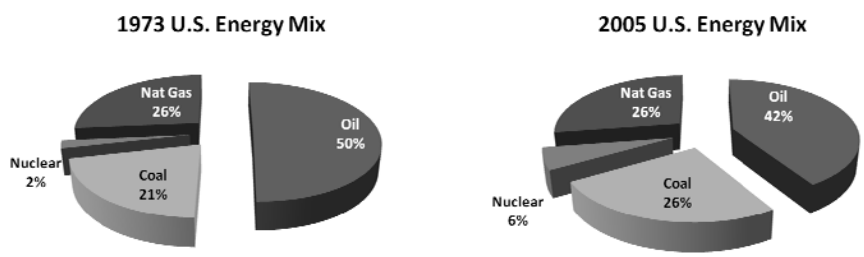

Figure 2. Comparison of U.S. Energy Mix in 1973 and 2005 [After: Tertkazian].

2. Breaking Standards

Once standards are set, they are difficult to change. The period of 1800 to 1920 was the most influential period in our modern era (Tertkazian, 2006). We are fixed in our approaches and options because of the technology developed in those days. The QWERTY keyboard standard was developed in 1872 to prevent typewriter hammers of frequently used letters from jamming (Tertzakian, 2007). There are probably more efficient ways to arrange the keys on a keyboard now since jamming hammers today is no longer a serious problem, however standards are hard to change and it is likely we will live with this standard far into the future. This report offers that breaking the QWERTY standard would be a much easier endeavor than breaking the world energy standard.

3. Insights

Three major insights were gained from *A Thousand Barrels a Second*. First, it is astonishing how the historical choices made in the past have created deep-rooted pathways and firm standards that severely limit the energy options available to the U.S. and DoD today. Second, geopolitical forces are again inspiring a global scramble to stake out energy claims and launching the world into a new era of volatility and risk. Finally, Tertzakian (2007) argues that new technologies will not provide the "magic bullet" to solve the world energy problems, and that energy technologies take decades to make an impact, unlike technologies in other industries. This may have been true in the past but it is purely speculative. To suggest that future rates of innovation and technological impact will follow the same general course as history shows might be excessively pessimistic. One can argue that the next great energy invention may not even be perceivable by mankind today. For example, a stunning breakthrough in fusion may truly be a "magic bullet."

C. BEYOND OIL: THE VIEW FROM HUBBERT'S PEAK — DEFFEYES

M. King Hubbert was a well-known geologist, most famous for predicting peak oil production. In his technique, he used mathematics to arrive at the answer as to when the world would reach its peak oil production. Using this data, his first prediction, in

1958, was that world oil production would peak in 1970. In 1969, he revised that number to argue that world oil production would peak in the year 2000.

1. Analysis

In the literature, *Beyond Oil: The View From Hubbert's Peak*, discussed in detail was the methodology that Hubbert used to predict his peak oil estimates. At first, U.S. oil production is examined on a yearly basis. Hubbert plotted oil production versus cumulative oil production between 1859 to 2003. His analysis was fairly straightforward because it used a straight line in order to simplify the results. Early on, the oil production data rested well above the line of best fit, but by 1958, U.S. oil production practically mirrored the line of best fit. As Deffeyes (2005) suggests, if you buy into this method, then it is easy to determine the point at which U.S. oil production will end. One of the criticisms toward this approach is that it only takes into consideration the undiscovered fraction of oil (because it was the simplest idea that could be tested) and nothing else mattered (Deffeyes, 2005). The author then suggests even that with 3-D seismic, deeper-water drilling, computer imaging and increased gas prices, there seems to be no abrupt dramatic improvement that will put an immediate bend in the straight line.

Examining the world picture, using the same format as mentioned above, the peak production point has moved to the right. Thus, the world's peak oil production would have peaked in late 2005, or early 2006. As the scarcity of oil begins to become realized, the prices of oil will likely continue to soar and DoD could find itself financially constrained in meeting national threats.

In addition to discussing Hubbert's method, this literature also discusses energy sources like coal, uranium, hydrogen and tar-sand oil. For each particular energy source, it discusses the benefits, environmental drawbacks, and the potential each one has in meeting U.S. energy requirements. While these sources of energy are available, they are not the long term solution. With current knowledge, it seems only renewable energy sources can provide clean, efficient, and secure energy as DoD looks to the future.

2. Insights

The main point of this literature was to show that we have, if you use and accept the Hubbert method, passed the peak production point for oil. However, there are some who criticize this method. Corsi (2005) suggests that Hubbert's Peak is a failed theory. According to the Hubbert, peak oil production occurred in late 2005, or early 2006. Corsi (2005) points out that in 2005, the EIA estimated that there was 1.28 trillion barrels of proven oil reserves worldwide, more that ever before in human history, despite decades of increased usage. Data estimates on world proven reserves of oil taken from the EIA website dated January 1, 2007, report that the Oil & Gas Journal estimated 1.317 trillion barrels of oil (EIA, 2007). This data estimate actually shows an increase in the proven world oil reserves and not the decrease Hubbert predicted should happen. ExxonMobil also discredits Hubbert's view. ExxonMobil claims that this theory does not match reality. ExxonMobil does agree that oil is a finite resource but because it is so incredibly large, peak oil will not occur for decades to come (ExxonMobil, n.d.). The author attempts to make a strong case that time is critically short to correct the pending energy crisis and that only a decisive change towards a diverse renewable energy portfolio is the answer to our future energy needs but as one can see, there are some who completely disagree. Somewhere in between both arguments lies the truth. Nevertheless, renewable energy should be developed as soon as possible to be ready for the inevitability of peak oil.

D. CORPORATE ENVIRONMENTAL POLICY AND GOVERNMENT REGULATION — JONES & BALDWIN

To achieve a corporate environmental policy is not an easy task. First you must be able to create a framework from which your policy can develop. According to Jones and Baldwin (1994), in order to create a sound environmental policy, eight variables should be considered:

- Increasing costs related to the environment.
- Consumer demand and market competition.
- Government regulation and enforcement practices.

- Actions and rulings by courts in support of environmental laws and challenges.
- Environmental interest group pressure.
- Public opinion.
- News media attention to corporate environmental problems.
- Culturally-based ethnic norms and perceptions of moral behavior.

Also discussed were five steps organizations can take to achieve environmental excellence:

- Develop program organization, staffing and resources.
- Develop an environmental policy with full participation of corporate management.
- Accomplish an environmental audit.
- Develop an implementation program including strong technical, legal and educational programs.
- Monitor trends and support similar interests.

1. Addressing Externalities

Another area covered was the environmental and political regulations to compensate for externalities. Here it discussed both positive and negative externalities and how that can affect corporate policy. Also, there is an effective argument made on how regulation can drastically influence corporate policy by examining the U.S. coal mining industry safety record from 1932 to 1976. This analysis shows that when regulators got involved in dictating safety rules, the mishap rates fell substantially.

2. Trends in Environmental Policy

Finally, future trends in corporate environmental policy were discussed. One corporate trend addressed was that there will be greater efforts to save on energy and waste disposal through research, investment and development of better technology. Another trend addressed was that corporations will begin to give more attention to public relations, in addition to advertising, about positive corporate environmental activities and benefits to local communities (Jones & Baldwin, 1994). In total, 16 trends were identified and they can be readily observed in today's corporate environment. In addition, 12 government regulatory trends were addressed. One of the most important trends addressed was that there is going to be increased efforts by government to set performance standards to which corporations must comply but not specifying the exact technology that should be used to achieve the end result (Jones & Baldwin, 1994). All of the trends mentioned are readily apparent in today's environment.

3. Insights

This book provided some interesting thoughts on corporate environmental policy and where it was headed into the future. As the push for going "green" continues to pick up steam throughout U.S. industry, the recommendations and guidance that were mentioned for creating a company's corporate strategy should be taken into consideration and implemented. Using these recommendations companies perhaps might be able to deliver a complete and robust environmental policy which can contribute to a decrease in costs and an increase in revenue.

E. ENERGY REVOLUTION: POLICIES FOR A SUSTAINABLE FUTURE — GELLER

1. Barriers

In his 2003 book, Geller provides an insightful guide to understanding the practical policy options for government and non-government leaders to create energy efficiency and replace fossil fuels. However, there are barriers limiting adoption of renewable energy and environmental efficiency for individual consumers, commercial industry, and the government including DoD. Generally speaking, the barriers can be categorized as technical, human behavior, market failures and flaws, and public policy institutions (Geller, 2003). With the exception of perhaps tax policies, these barriers all have similar deterrent effects on both public and non-public sectors. Financing opportunities are available to DoD, but in a more advantageous manner than to non-government entities. This will be discussed in detail later. Strong financial incentives and regulations can overcome these barriers, especially with the actions and support of a large government agency such as DoD. Strong financial incentives and regulations should be pushed to overcome these barriers and an agency as large and powerful as the DoD might be able to become a catalyst for change.

a. Technical Barriers

A glaring shortfall in the budding renewable energy industry is the limited supply, storage, and distribution infrastructure. For example, photovoltaic systems are relatively easy to setup and stand alone when used for small decentralized applications. However, for large scale centralized solar energy systems like solar thermal heating, storage and distribution to customers are still large hurdles to leap. Complimentary technologies like lithium ion battery science and energy transmission technologies for example must advance rapidly enough to keep pace with energy generation technology.

Adoption of environmental efficiency is impeded by insufficient information and training, and quality problems (Geller, 2003). As a simple example, architects and builders may lack know-how to design and build energy efficient buildings. Also in existing older buildings, poor quality may be revealed in improperly installed or oversized air conditioning units which increase energy consumption. Energy efficient lamps and lighting ballasts produced low light output and premature failure when initially introduced but has improved a great deal since.

b. Human Behavior

It is often difficult for policy makers, planners and decision makers to consider the long-term effects of their actions and choices. The high initial capital costs of renewable energy systems and environmental efficiency are often a deterrent for adopting these technologies, and “least initial cost” thinking prevails over “least life-cycle” cost thinking. In the U.S., energy costs represent one to two percent of the total costs of production for manufacturing industries other than energy intensive industries like aluminum, steel and paper manufacturing (Geller, 2003). With this in mind, many companies do not take advantage of opportunities to raise their long-term profits by increasing energy productivity and efficiency, but instead focus on least initial cost for improvements. Similarly, Defense contractors are usually awarded on the basis of lowest-price bids, thus encouraging cutting corners to save money except when certain energy codes must be met.

The deterrent of high up front costs has somewhat eased since the author reported these findings over 2002 and 2003. Five years later, new financing strategies are finally making it possible for interested users to benefit from renewable energy technology. Recently, several companies have shown dedication to dispel the up-front costs. The two popular strategies that have emerged are the use of loans to amortize costs over a systems entire life span, and Power Purchase Agreements (PPA) (Winnie, 2008). Purchasers who amortize are given the option by some lenders to refinance an entire home mortgage and incorporate solar costs into the regular monthly payments. PPAs work similar to how cable TV is paid for. Suppliers install the necessary equipment, and the customer pays for the services made available at a fixed price over the term of the contract. This could become beneficial over the long term for customers locking in a rate for 30 years while utility prices rise. The reality still is that solar energy costs about two to five times more than normal residential electricity rates depending on geographical location (Winnie, 2008). But, when one considers the ability for owners to market properties as "green" and charge a higher rent or sales price, as well as enjoying a fixed utility rate, subsidies, rebates and tax incentives, this barrier is being softened.

c. Market Failures and Flaws

Externalities are the unintended consequences of certain market activities that impact society in a negative or positive fashion; they are also market failures or flaws. These flaws tie into human behavior barriers mentioned above. According to Geller (2003), the prime motivator for government and industry to put off adoption of renewable energy is their focus on short-term profits (or savings) rather than longer term social and economic benefits. What may also be a factor is that political and governmental bodies have not internalized the externalities and created national-level mandatory solutions to correct them.

The additional costs to society for continued dependence on fossil fuels are not usually factored when comparing energy costs of today with renewable energy costs. Additionally, electricity prices often do not reflect the full cost of electricity grid and generator extension (Geller, 2003). This and the political failure to include the social and environmental externalities of air, water, and land pollution; climate change; military expenditures to protect oil supplies and fight wars; and economic upheaval caused by oil price shocks leads to negligent policymaking, continued excessive fossil fuel consumption, and disagreement about which renewable energy technologies provide the best cost benefits.

The two prevailing market solutions that have been offered in order to correct this market flaw and encourage oil and gas companies, refineries and other major industrial sectors to reduce carbon dioxide emission are a carbon tax, and a "cap and trade system." Carbon taxes are taxes applied by a government to a utility or company for exceeding a certain cap on carbon dioxide emissions. Under a "cap-and-trade" system, a government rations the amount of carbon dioxide and other greenhouse gases that businesses emit by issuing permits. A business wanting to emit more than its entitlement can buy the right to do so from another business that emits less than its entitlement (Liebreich, 2008). In 2008, Daniel Yergin, Chairman of Cambridge Energy Research Associates, stated that economists generally favor a carbon tax over a "cap-a-trade" system to incentivize reduced emissions (Dittrick, 2008). The United States has neither of these programs on a national level. There are state and local level carbon tax policies and a volunteer "cap-and-trade" system facilitated by the Chicago Climate Exchange (CCX) however. Members of CCX include Ford Motor Company and other companies, counties, city municipalities, state governments, and universities. There are no DoD organizations voluntarily participating in the CCX "cape-and-trade" system at the time of this writing. Perhaps the reason that corporations and non-government organizations are voluntarily participating is that they value the favorable trust and reputation gained with the public by participating, whereas government agencies are motivated by politics and congressional mandates. If this is true, a political failure has delayed national adoption of a carbon-limiting program.

European Union (EU) launched a national "cap-and-trade" system in 2005. The system was supposed to be a financial incentive for industries to clean up their act and meet commitments of the Kyoto Protocol. Results of a study completed in April 2008 by Oslo-based Point Carbon revealed that carbon dioxide emission actually rose about one percent each year despite the program (Abboud, 2008). Point Carbon's report stated that the caps were too high and that there were too many government permits issued (Abboud, 2008). Proponents of both systems are optimistic that national-level coordination of market solutions for reducing greenhouse gas emissions and adopting renewable energy will be legislated in the next four to five years.

d. Public Policy Institutions

Prices, regulations and tax barriers have played a major role in deterring mainstream renewable energy acceptance. For consumers and businesses with limited capital, renewable energy systems are unattractive due to the long payback on the investment, although with current oil prices climbing and depending on the prevailing alternatives' prices, the tide may be changing since Geller made this argument. For renewable energy systems, virtually all costs are realized up front and banks are still reluctant to provide favorable long term financing due to limited understanding and low confidence in the technology (Geller, 2003). This will be overcome only when renewable energy becomes widely adopted, which cannot occur until long term financing becomes more available, and the vicious cycle continues.

The utilities industry is a powerful economic segment in the United States which creates onerous barriers such as expensive interconnection requirements, poor buyback rates of excess production (or refusal), and burdensome application procedures (Geller, 2003). The majority of political voices favor continued fossil fuel use due to familiarity, tradition and the inherent economic strength and political clout of conventional energy. Since the renewable energy industry is immature and much less influential, vested interests in fossil fuels can exert political pressure to block policies favorable to renewable energy. In the U.S., the subsidizing of conventional energy sources is an enormous barrier to overcome. From 1947 to 1999, the government subsidized utility companies in excess of $145 billion (CY$99). Equally shocking, tax incentives amounted to $140 billion during 1968 to 2000 (CY$00) (Geller, 2003).

Current tax policy concerning renewable energy projects requires that capital costs be depreciated over thirty years or more. Again, with no fuel costs and virtually all renewable energy costs realized up front, this can be very challenging except for very well funded or financed organizations. On the contrary, businesses are allowed to deduct fossil fuel purchases from revenues when calculating income taxes (Geller, 2003).

F. DOD CURRENT POSITION IN THE RENEWABLE ENERGY MARKET: REVIEW OF GOVERNMENT RESEARCH AND POLICY SOURCES

So what are the implications of fossil fuel dependence for DoD? As oil prices continue to rise amid growing demand and shrinking supply, DoD will likely continue to pay the price required to complete its missions. If supplies become severely constrained either by political, geological and economic factors, DoD will certainly get its requirements filled before the public for the sake of national security.

Reflecting greater awareness of this and greater concern about the consequences fossil fuels-induced global warming will have on national security, the Defense Authorization Act of 2007 calls for huge increases by the Pentagon in its use of renewable energy resources. By 2025, DoD is "to produce or procure not less than 25%" of its total energy needs from renewable sources. Currently, DoD derives about 9 percent of its total energy needs from renewables, nearly double that of the U.S. as a whole (Hilburn, 2007). Even more impressive, as of October 2007, the U.S. Air Force ranked forth in the U.S. Environmental Protection Agency (EPA) Green Power Partnership Top 25 for “green” power consumption (EPA, 2007). It also ranked number one among all government organizations. This is certainly a step in the right direction for the DoD. The consumption of renewable energy is evident in the EPA ranking and by seeing the solar and wind structures at such sites as U.S. Army’s Fort Bliss, Texas and Kirtland Air Force Base.

But, is DoD also a research and innovation force in the renewable energy industry? Agencies such as Defense Advanced Research Projects Agency (DARPA) and Construction Engineering Research Laboratory (CERL) are contributing to new technology development and improvement, although to date, only a very small fraction, approximately two percent on average, of each agency's total research and development (R&D) budget goes into renewable energy development. The majority of R&D funding has been dedicated to weapons systems and homeland security since 2001.

White House strategy experts, however, have recently been placing more recognition on the significance that energy dependence has on homeland security. The 2006 U.S. National Security Strategy (NSS) for instance contains much more language on this correlation than the 2002 strategy. In 2002, just one short paragraph stated that the U.S. desires to expand economic liberty and prosperity by promoting clean energy development. There is no further mention of energy, energy security, or renewable energy technology development. On the other hand, the 2006 NSS defines a comprehensive energy strategy that puts a priority on reducing our reliance on foreign energy sources, while acknowledging that energy dependence is irresponsible and not sustainable. Also in NSS 2006, the White House vows to accelerate deployment of clean energy technologies including revolutionary solar and wind technologies in order to diversify energy markets and ensure national security (NSS, 2006).

This thesis explores how DoD may be able to increase R&D spending, accelerate adoption of business processes and innovative strategies of successful firms like Toyota, General Electric (GE) and British Petroleum (BP), and learn from the successes of foreign governments like Brazil, Sweden, Germany, and Japan. Doing so will arguably improve DoD's operational capacity and combat power through energy efficiency. It can hardly be argued that DoD's effectiveness in waging combat recently is flawed. However, it might be easy to find flaw in its efficiency to do so. During this decade in the corporate world, there has been strong evidence that energy efficiency-minded culture and operations correlate strongly to corporate efficiency, survivability and profitability (Esty & Winston, 2006). Esty and Winston were granted access to environmental professionals, factory managers, board members, Chief Operating Officers (COO) and

Chief Executive Officers (CEO) at more than 100 leading companies across a diverse array of industries. Their exploration revealed several dozen of these companies such as Johnson & Johnson, BP, 3M, DuPont, Nike, and Sony using environmental strategy to innovate, create value, and achieve competitive advantage. The inference that DoD can certainly benefit from this amid increasingly greater downward financial pressure will be discussed in later chapters.

G. WIND AND SOLAR POWER SYSTEMS — PATEL

This particular literature addressed the technical aspects of wind and solar power systems and provided an overview of the current energy industry. It addressed the current situations with China and India, who are rapidly becoming more demanding customers of increased energy needs. For example, in 2005, the worldwide demand of 15 trillion kWh was projected to reach 19 trillion kWh by 2015, which constitutes a worldwide average growth of 2.6 percent. The dilemma, however, is on how to meet that demand.

1. Wind Power Development

Wind power offers one way to combat the increase in demand and cost for electricity. One of the arguments suggesting that wind power is becoming more cost effective is that new technology development is reducing installation costs and increasing energy efficiency. For example, the variable speed operation of electric generators has allowed wind systems to capture the maximum amount of energy possible. One of the interesting comparisons that this book makes is the development and installation of wind power systems between Europe and the United States. While the United States is beginning to generate more electricity from wind power, it lags far behind Europe in added capacity. Figure 3 shows a graphical representation of this difference. Finally, it discusses the components of wind power systems such as the tower structure, rotors, electrical generator and sensors and controls.

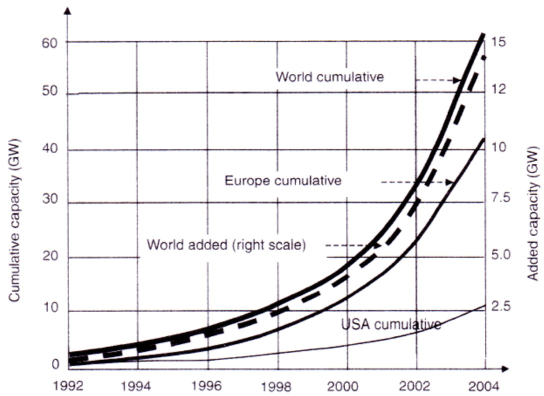

Figure 3. Added and Cumulative Wind Power Capacity in Europe, U.S. and the World [From: Patel].

2. Solar Power Development

This book also provides an in-depth analysis of photovoltaic (PV) power systems. It discussed how the module and arrays are constructed, how the sun intensity, angle, load matching for maximum power, and operating temperature can all influence the design of these systems. In addition, it also discusses at length energy storage techniques such as battery storage. According to the literature, there are two types of battery storage: primary storage and secondary storage (aka. rechargeable battery). The primary storage converts chemical energy into electric energy but because it is nonreversible it must be discarded after each use (Patel, 2006). The secondary storage is reversible so it can be used over and over again. Six major types of rechargeable batteries are discussed ,comparing cost, efficiency, and how they react to certain environmental conditions.

Finally, there is a brief discussion on the future of renewable energy. It addresses the increasing world demand for electricity, reduction in production costs, the forecasted growth rates for both solar and wind technology, and the current legislation that directly affects renewable energy. To summarize the impact that renewable energies can have, the book makes the case of the 2003 blackout across the northeast and Canada. This blackout affected 50 million people and the cost of the outage to the U.S. economy was estimated at $10 billion, excluding personal losses (Patel, 2006). Can we afford another blackout of the same magnitude or worse?

3. Insights

Wind and Solar Power Systems: Design, Analysis and Operation was written as a technical textbook, however it did provide a beginner's look into how wind and solar power systems are produced, the materials needed and how they can have an impact in today's energy market. As the production costs continue to decline for both wind and solar systems and become more competitive with the fossil fuel energies, it becomes easier to create a diverse portfolio of renewable energy systems.

H. THE SOLAR ECONOMY — SCHEER

This book provides an in-depth look at the comparison between the fossil fuel and solar supply chain. Using a variety of data, charts and graphs, it suggests that when the total cost is compared between the fossil fuel supply chain and the solar supply chain, solar power provides a considerable benefit in the reduction of both economic and environmental costs. One way in which to argue this point is to examine the economic logic of the solar supply chain. For example, the solar power supply chain is extremely short compared to the complex supply chain of fossil fuels because it converts the sun's rays directly into energy, which then can be inserted into the electrical grid or stand-alone system. As the supply chain becomes shorter, it creates smaller distinct processing steps, which result in lower infrastructure costs.

Another argument to support the attractiveness of solar energy is based on the political cost of fuel and resource conflict. For this particular argument, the case for transitioning to solar power (and other renewable energy sources) is made by discussing the limited oil and mineral reserves that the world faces along with the ever increasing energy consumption by developing nations like India and China. In the political arena, as the dwindling of fossil fuel supplies continue, it will create or break political alliances as countries seek to avoid fuel starvation.

A third area that is examined is the profitability of renewable energy and resources. Here the case is made that the quicker and more comprehensively fossil energy and resources can be supplanted by their solar counterparts, the greater the cost saving to society and the less strain on government budgets threatened by ever higher clean-up costs in the wake of fossil-fuel-induced catastrophe. In addition, an in-depth analysis of solar energy costs, both on the operational and the initial capital investment is examined.

Finally, a deeper look at the impact of solar energy beyond the energy grid is examined in which the author poses the argument that the potential impact stand-alone energy systems can have on products. For example, if mobile phone batteries could be recharged using solar power, then the users would never have to worry about running out of power, or if laptop computers had solar cells in their lids, they could be recharging the batteries while in use (Scheer, 2005).

One of the main points that must be taken into consideration is that when the costs of solar power and fossil fuels are compared, in whole and on a level field, solar power provides a more economical and environmental benefit than fossil fuels in certain applications. From a DoD stand point, solar power offers an opportunity to drastically reduce operations and maintenance costs to which the money that was being spent on these costs could be used to improve battlefield technology to give our military forces the competitive edge they will need in the future. By examining the potential impact solar power can have in our lives and in our economy, there becomes a sense of urgency to convert many energy requirements to solar power before it is too late.

I. SOLAR REVOLUTION: THE ECONOMIC TRANSFORMATION OF THE GLOBAL ENERGY INDUSTRY — BRADFORD

The field of alternative energy sources is growing in scope and volume and each choice carries practical considerations and obstacles to adoption. Travis Bradford, in *Solar Revolution: The Economic Transformation of the Global Energy Industry,* suggests that solar energy will inevitably become the most economic solution for most energy applications in the future due to certain projected cost advantages compared to other energy sources. He also acknowledges that solar energy is not quite competitive enough yet, but is optimistic about the rapid innovation and development of the field. The specifics of solar and current electric utility economics and the impact on DoD will be discussed in later chapters.

1. Risk Factors for Status Quo

The combination of fossil fuel peaking, potential supply disruption, and an aging electricity grid puts the future of conventional energy at risk in every part of the energy supply chain. Not responding to the dire realities the world is facing may spell disaster and invite the consequences of these risks. Bradford (2006) argues that with over six billion people on the planet today, and projections for ten billion by 2050, resource scarcity will plague humanity at an accelerating rate causing greater gaps between rich and poor, and more international conflict. He speculates that along with these risks of inaction are increased food shortages, pollution, climate change and the famine and devastation each brings. This is not the first time that this has been pondered. In 1968, *The Population Bomb* by Paul Ehrlich warned that in the 1970s the world would experience famines resulting in hundreds of millions of people starving to death. The same fear cropped up again at the United Nations World Food Summit in 1996 (Simon, 1996). Thankfully, such terrible scenarios have not materialized as a result of productivity innovations and substitutes. Therefore, although resource scarcity may not be as substantial a concern as suggested by the author, the aging electricity grid might pose the greatest risk. From numerous major blackouts, to the fuel crisis of 1973-1974 and the Three Mile Island accident, there have been very few years when the grid has not had to deal with crisis (Bradford, 2006). Since federal deregulation of utilities, the likelihood of action and funding for grid upgrades has diminished. DoD should consider the national security challenges these risks spell for the nation’s future.

2. Solar Energy Storage Solutions

With productive sunshine in the range of 6 to 10 hours on average each day in the sunniest regions of the world, the combination of all solar technologies – centralized PV, remote PV, solar thermal electricity, and concentrating solar power all face the challenging limitation of storage. There are technical limits to widespread adoption beyond 15 percent of total U.S. grid capacity without the added inclusion of energy storage solutions (Bradford, 2006). Large-scale energy-storage applications are being tested in the form of pumped hydro, compressed air, hydrogen fuel cells, or advanced flywheels to supply power during periods of low or no sun (Bradford, 2006). An indirect storage mechanism is to produce excess solar electricity during the daytime, sell back the excess to the grid, then using the grid to supply periods of low or no sun. Hence, the grid becomes the storage medium. Small-scale portable applications rely mainly on portable batteries.

An innovative idea has been suggested by Sanyo Electric to eliminate the need for storage altogether. The basic idea is that a global infrastructure project would interconnect the whole world's electric grid through efficient, high capacity transmission lines. This alternative, called Project Genesis would allow the day side of the world to sell power to the night side of the world. The proposal has numerous problems – for example, the transmission lines would have to be added to the EIA's list of vulnerable energy "chokepoints"—but highlights that there is innovating thinking going on (Bradford, 2006). Bob Fisherman, a senior manager at Ausra, Inc., developers of solar thermal electricity technology, believes that thermal storage is the most efficient and cost effective mode of storage to date (personal communication, March 25, 2008). Ausra's systems rely on large super-insulated tanks to store the pressurized super-heated water to allow several hours of steam to generators, long after the sun has set or become cloud covered.

Whatever direction storage may be heading in into the future, the options discussed are complementary technologies that have unbounded headroom for improvement. Innovation and development will play a large part in the rate of future solar energy adoption.

3. Accelerating Adoption

Bradford (2006) argues that the prime mover for accelerating adoption of solar energy is through encouragement of social benefits through coordinated government and industry efforts. Specifically, tax rebates, cash subsidies, mandates for utilities to accept excess generated electricity all enable and encourage market acceptance. Additionally, pollution penalties, taxes, and removal of subsidies for conventional oil and gas sources would accelerate adoption. Japan and Germany represent success stories where government and industry worked synergistically to create demand and enable market access of solar energy through subsidies, rebates and other incentives. Their robust solar energy programs are decades ahead of the U.S. According to Bradford (2006), the U.S. has much room for improvement in this area. The DOE, primarily through NREL, spent $212 million in 2004 for renewable energy research and development. Besides this, and a law congress passed in 2005 for a two year 30 percent residential tax credit, research and development and incentive funding has primarily been led by state governments and private sector initiatives.

4. Insights

Maintaining the status quo is arguably not the way the world should handle the looming energy crisis and all the chaos predicted to result. There are risks being taken now in the U.S., mostly by commercial enterprises, to force out the next solution. In the case of creating a future solar world far beyond the technical capabilities of today, market influences and timing alone can create and deliver the necessary innovative technologies in which all the risks of uncertainty and failure are born by the private sector. Alternatively, a powerful government agency like DoD can bear the risk, or a cooperative achievement blending the two.

J. GREEN TO GOLD: HOW SMART COMPANIES USE ENVIRONMENTAL STRATEGY TO INNOVATE, CREATE VALUE, AND BUILD COMPETITIVE ADVANTAGE – ESTY & WINSTON

There is a green wave sweeping the business world and it is defining how twenty-first century corporate leaders may improve their company’s performance, efficiency and sustainability by developing key partnerships, and integrating environmental stewardship into their corporate culture. The green wave encompasses the use of renewable energy sources as well as reducing harmful outputs to the environment. Esty and Winston (2006) assert that there is logic for making environmental thinking a core part of strategy, and that globalization gives the environmental imperative greater prominence. The business case for environmental thinking focuses on capitalizing on the upside benefits, managing the downside risks, while taking a value-based concern for environmental stewardship (Esty & Winston, 2006). Although it seems logical to apply these activities to the corporate world, other non-governmental and governmental agencies like DoD might benefit from the insights gained from studying these issues.

There are natural and human pressures bearing down on companies and DoD today that were much less prominent decades ago. From ozone depletion, to climate change, fresh water shortages, deforestation, and pollution, every action and decision by private and public leaders are subject to more watchful scrutiny than ever before. One of the key arguments in *Green to Gold* is that successful companies enjoy greater efficiencies and profit when they see emerging issues ahead of the pack and are better prepared to handle unpredictable forces (Esty & Winston, 2006). But, one can counter-argue quite easily that successful companies cannot really see emerging issues, but rather make bold choices and decisions that turn out favorable. Armed with hindsight, a firm might be inclined to say they predicted and overcame emerging issues, but in reality, they were probably just lucky. Merit should be given to strong leadership and adaptability however. Rapidly becoming the world's largest automaker, Toyota Motor Corporation laid down fundamental principals in 1935 (Stewart & Raman, 2007) that allowed them to prepare themselves for the energy challenges of the twenty-first century. In the early 1990's, when gasoline was cheap, and making the environment a major theme was against the grain, they began work on the first hybrid electric-gasoline automobile. The Prius was introduced worldwide in 2001, and by 2004, when Prius earned the honor of Motor Trend's Car of the Year (Esty & Winston, 2006), consumers were willing to wait months to get their hands on one.

1. Eco Advantage

The success of the Prius can be attributed to what Esty and Winston (2006) refer to as "Eco Advantage." They propose that the leading edge companies go beyond the basics of environmental compliance by:

- Pushing suppliers to be better environmental stewards.

- Designing innovative products that are environment friendly.
- Tracking their environmental performance.
- Partnering with non-governmental organizations (NGO) and other stakeholders to find innovative solutions to energy problems and environmental problems.
- Building an Eco Advantage culture to engage all employees in the vision.

The bottom line to Eco Advantage is that stakeholders (watchdogs, agenda setters, business partners, communities, etc.) are increasing in number, power and diversity (Esty & Winston, 2006) and the importance of have an Eco Advantage mindset cannot be understated. Organizations should look for opportunities to connect with critical players, friendly and hostile, and build relationships and networks that may strengthen this advantage, even before they are needed.

2. Strategy

Finding critical connections and building relationships are the cornerstones of an effective organizational strategy that seeks Eco Advantage. Esty and Winston (2006) emphasize the importance of building the potential for upside benefits through meeting or exceeding stakeholder needs and by building a reputation of trust and loyalty to environmental preservation. For example, watchdog agencies like Greenpeace, Heritage Foundation and World Wildlife Fund have the power to paint a favorable or unfavorable image of companies that can critically impact customer loyalty and sustainability. Also, the authors contend that managing downside risks improves resource productivity, cuts environmental and regulatory burden, and increases value chain efficiency by lowering costs upstream and downstream.

Establishing an Eco Advantage mindset starts with top leadership. They must set the vision, establish tough goals, and persist. Those companies that do the right thing for the sake of fulfilling the vision and meeting goals without indication of immediate benefit minimize adversarial relationships with regulators and minimize risk of environmental-related disaster. This lesson can be learned from the incident that befell Dupont in 1997. A Conoco oil tanker (owned by Dupont) collided with a tugboat near Lake Charles, Louisiana, opening up a hundred-foot gash in the tanker. Fortunately, not a drop of oil was spilled because Dupont made an expensive commitment in 1990 to build only double hull ships (Esty & Winston, 2006). Executives believed, during a time when green issues were off the radar screen, that the reduction in risk to the company and the environment was worth it.

3. Insights

Alternative energy and environmental awareness are gaining market and policy-maker attention due to national security concerns, pollution, and climate change concerns. Organizations that adopt strategies for building Eco Advantage are tapping into a new competitive advantage and minimizing risk. Moreover, environmental efficiency seems to equate to business efficiency and success in many other areas.

DoD is arguably the most effective war fighting institution in the world, yet its efficiency in developing weapons, managing programs, deploying forces and making decisions may not garner such praise. There may be important actions DoD can take to create value, innovate and improve efficiency.

III. SOLAR POWER IMPACT IN THE NEXT FIVE YEARS

A. INTRODUCTION

Solar power and other alternative energy sources are becoming more popular as oil and gas prices continue to rise. For example, over the past few years, according to the European PV industry, global PV cell production has been growing annually by 30 percent and is expected to continue on this upward trend (Patel, 2006) while a survey conducted by Photon International in 2006 states that annual growth was closer to 40 percent (Hariharan, Sato, & Liu, 2008). In addition, the Prometheus Institute for Sustainable Development estimates that PV costs will decrease by 40 percent over the next three years due to combined technology advances and the increase in polysilicon supply (Renewable Energy World, 2007). Figure 4 illustrates the current and projected trend in PV energy efficiency, and as a comparison, it also illustrates the efficiency for biomass plants. Note that while PV solar power does not match the efficiency of biomass plants, its efficiency is steadily improving. As further research and technological improvements occur within the industry, solar power can, perhaps, become a significant part of DoD's portfolio in creating a long-term strategic energy vision. In 2006, a new breakthrough in efficiency took place as Boeing-Spectrolab used a concentrator solar cell to achieve 40.7 percent efficiency (Kielich, 2006).

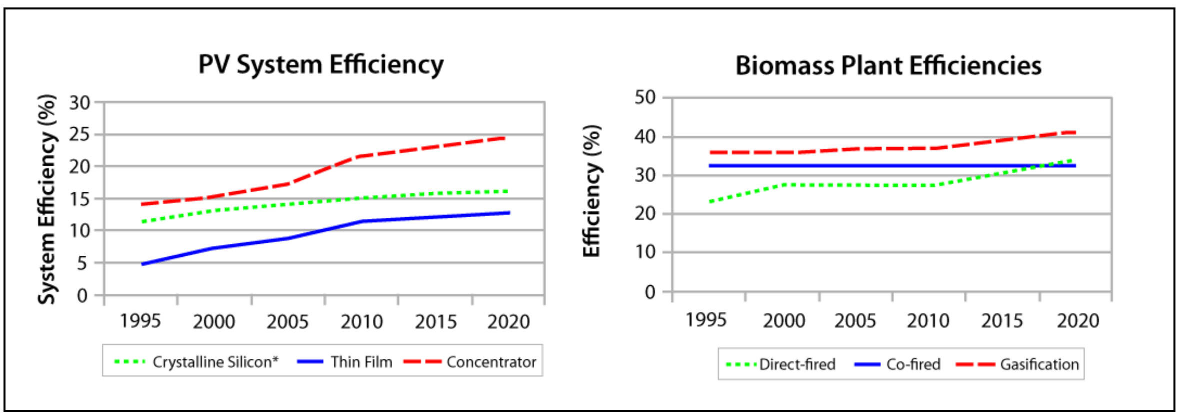

Figure 4. PV versus Biomass Efficiency [From: U.S. Department of Energy].

1. Logic of Solar Power

In many ways, solar energy is already priced competitively with coal and oil when long-term fuel costs and infrastructure maintenance costs are considered. Additionally, most of the world regions that DoD has been operating in since the end of World War II have the most solar energy production per unit area and unreliable electricity infrastructures. Figure 5 below depicts solar energy abundance in North Africa, the Middle East, and South Asia. The 2006 NSS continues to place these regions very high on the list of national interests. Specifically, in choosing leadership over isolationism, the U.S. is committed to free and fair trade, and global economic growth; and vows to oppose tyrannical regimes such as Democratic Republic of Korea (DPRK), Iran, Syria, Cuba, Belarus, Burma, and Zimbabwe among others. Iran and Syria are singled out as key states that harbor terrorists, seek weapons of mass destruction (WMD), threaten Israel, and disrupt progress in Iraq (NSS, 2006).

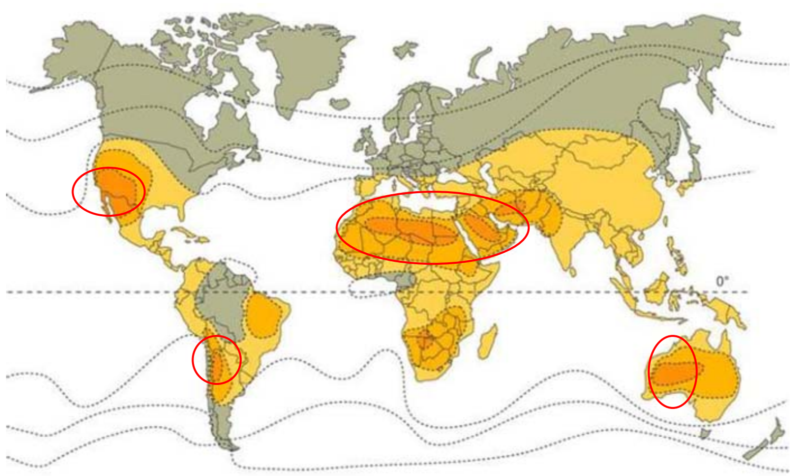

Figure 5. Ideal locations for Solar Power (CSP) [After: Marker].

Similarly, the U.S. National Defense Strategy (NDS) is a layered approach to the defense of the nation and its interests and is derived and designed to execute the NSS. One crucially important operational capability of the NDS is projecting and sustaining forces in distant anti-access environments (NDS, 2005). These are remote, hostile environments where fuel, electricity, potable water and supplies are very difficult to acquire locally. DoD endeavors to extensively project and sustain forces in remote environments with uninterrupted resources. Portable solar energy systems are ideally suited to provide reliable energy to operating forces in these remote environments because they do not require the extensive support or have a major footprint like other renewable energy sources such as geothermal or wind. Also, long term main operating bases can benefit from larger, less portable systems like solar thermal energy plants and provide the uninterrupted energy needed for electricity, fuel, and potable water generation.

B. SUPPLY CHAIN ANALYSIS

1. Fossil Fuels

The fossil fuel supply chain begins with the countries that possess the reserves. The main concern for DoD is that most of the leading countries that harness the majority of the proven world oil reserves are not considered close allies of the United States. For example, as of January 1, 2007, of the top twenty countries that have proven oil reserves, only one, Canada, could be considered a close ally[1]. Unfortunately, Canada only possesses 13.6 percent while the remaining countries, excluding the United States, hold an overwhelming 84.7 percent of the proven world oil reserves (EIA, 2007). Recently, the extraction of fossil fuels has become a very complex and capital-intensive process as sources diminish (Scheer, 2005). Once the fuel is extracted from the ground, it must then be transported, usually over vast distances via pipeline, rail, sea or road, to a refinery where it is then processed and then stored. The next step in the supply chain is to transport the refined fuel to oil-fired power stations via tanker truck or pipelines. At this point, the fuel is converted into high voltage electricity and imported into the national

1 The vast majority of Canada's oil reserves are located in Alberta, Canada in the form of oil sands. From a production stand point are attractive economically because, according to Canadian Oil Sands Trust, their first quarter production costs in 2008 were $35.93 a barrel (Canadian Oil Sands Trust, 2008). This is still well below the current price of crude oil which has broken the $110/barrel mark. However, the extraction and refinement of the oil sands (aka: tar sands) can have a significant cost if the environmental cost is associated with their production due to the carbon dioxide emissions produced during the production phases.

grid. Once in the national grid, the electricity is converted from high to low voltage in order to be able to distribute it to the general population.

The United States, because of the relative proximity, purchases over 50 percent of Venezuela's exported oil (Walsh, 2007). This dependence of oil from a country that is extremely critical of the United States should be a concern in our national strategy. However, this dependence could also be used as a leverage tool by the U.S. in foreign policy. Venezuela's economy is almost solely dependent upon oil revenues as they make up 80 percent of the country's export revenues, which contribute to the funding of social programs, public works and defense (Alvarez, 2006). Teslik (2007) suggests with so much dependence on American purchasing of Venezuelan oil at 60 percent of their exports while the Venezuelan imports only contribute to 11 percent of U.S. imports, the U.S. clearly has leverage to influence current Venezuelan policy. Unfortunately, Venezuela is looking to broaden its ties with China and other clients in order to diversify and lessen the country's dependence on the United States (Alvarez, 2006). Still, Venezuelan dependence on the U.S. will continue for the foreseeable future, so the potential for any radical action by Venezuela is remote. However, the dependence on Venezuelan oil is still important and, if the flow of oil was cut off, an impact would be felt across America; higher oil prices could possibly stunt or slow economic growth. Solar power, with its emerging solar technologies, can play an important role in reducing the dependence of importing our energy requirements from nations that are considered hostile to the U.S..

2. Solar Power

Solar power may offer DoD an unique way to re-examine its strategy on providing reliable energy, operational planning and long term sustainability. The solar supply chain is very different from fossil fuels. In fact, most renewable energy sources provide a much shorter supply chain than fossil fuel choices. Solar power's supply chain is quite simple. The sun light is absorbed by PV cells, converted into low-voltage electricity and then delivered to the end user. Because there are little or no moving parts, the operation and maintenance costs of these systems are relatively small. In addition, PV solar cells are very quiet and do not release any harmful emissions into the atmosphere.

The economic logic of solar power as an energy provider is clear. The shorter the supply chain – i.e., the smaller the number of distinct processing steps involved, the greater the scope for reducing the costs of energy generation (Scheer, 2005). Smaller supply chains have the potential to offer more productivity. For example, because the fossil fuel supply chain is considerably larger than that of solar power, it will result in the loss of the final energy output. To illustrate this point, the process of delivering energy through solar power is more efficient – fewer processes – than fossil fuels so the end result is that solar power systems will not require the same amount of energy input to make them produce electricity. Figure 6 provides a visual comparison between the solar power supply chain and the traditional conventional fuel supply chains.

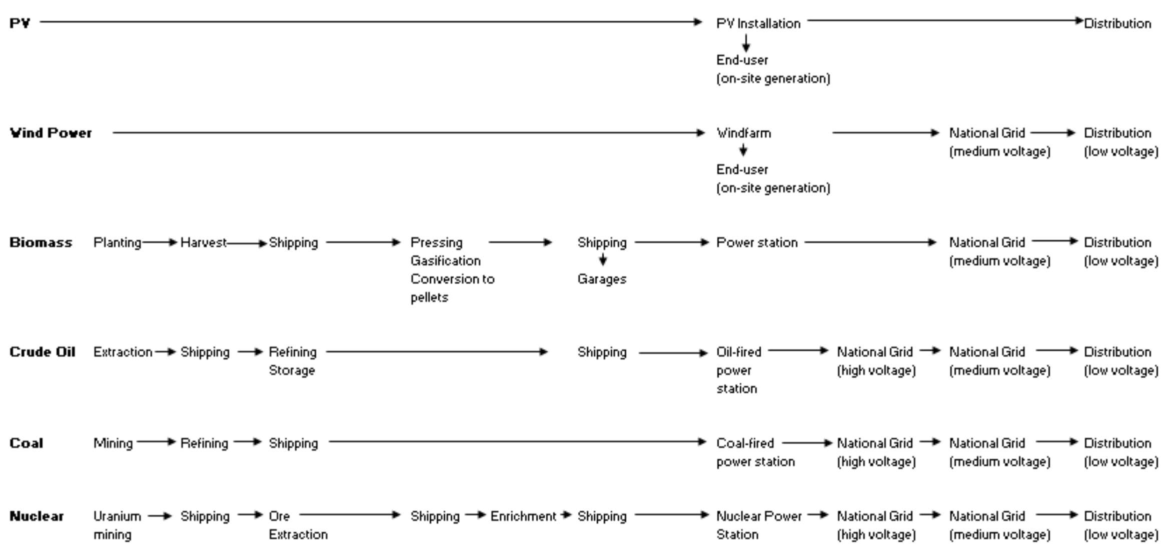

Figure 6. Comparison of Energy Supply Chains [From: Scheer].

3. Summary

If we take the traditional mindset to energy consumption and production, our society may not be able to cope with an energy crisis that some predict is about to materialize. Solar energy offers a unique opportunity to break that mindset and establish a long range strategy for energy consumption. DoD perhaps should realize by comparing the solar power supply chain against that of fossil fuels, that solar power has distinct advantages over fossil fuels. Case in point, as Figure 6 clearly shows, solar power energy can be more rapidly deployed because it does not require the extensive infrastructure that is required to support the fossil fuel energy consumption. In addition, DoD should also take into the consideration the costs associated with the solar and fossil fuel supply chains. After a thorough and fair analysis, Scheer (2005) states the results will clearly be in favor of solar energy. Finally, solar power can help, along with other alternative energy sources, secure DoD's energy requirements well into the future.

C. FINANCIAL IMPACT ON DOD

1. Iraq and Afghanistan

The United States military doctrine was completely altered on September 11, 2001. DoD was now faced with a new challenge that was unlike anything they had been accustomed to before. Our enemy was no longer a nation but an ideology. Now, there would be no more distinguishable frontlines like those of the previous wars we had fought. As American and coalition forces engaged the terrorists in Afghanistan and then later in Iraq, it was becoming more inevitable that our forces could be there for quite some time. In addition, time would soon show that there would have to be a significant presence of coalition forces in Iraq and Afghanistan in order to win the war on terror. As with any large scale operation, it will require a lot of energy to sustain this presence. Solar power can be a key ingredient for the solution to the energy dilemma in Iraq and Afghanistan.

a. Benefits of Solar Power

Solar power, as with other renewable energies, can be a major player in the energy industry as long as we can let go of our current method of thinking that fossil fuel is still the cheapest and easiest method to use. As stated before, one of the clear benefits of solar power is the short supply chain it has associated with it. This short supply chain for solar power can have a significant impact on the operational strains our forces have in supplying bases and outposts with energy. For example, if bases in Iraq and Afghanistan were to use solar power to sustain their energy requirements, it would significantly reduce the cost of transportation of refueling convoys, their escorts, maintenance, and the manpower cost. In July, 2006 Maj. Gen. Richard Zilmer, the highest-ranking Marine Corps officer in Iraq's Anbar Province, characterized the development of solar and wind power, "By reducing the need for [petroleum-based fuels] at our outlying bases, we can decrease the frequency of logistic convoys on the road, thereby reducing the danger to our Marines, soldiers, and sailors" (Crowley et al., 2007). To further this point, Dimotakis et al. (2006) stated that the present logistic supply chain was designed at a time when "behind the front lines" denoted more-or-less safe terrain and further stated that fuel supply vehicles are not armored and, as a consequence, present a vulnerable target and costly liability in terms of lives and treasure for U.S. forces. Dimotakis et al. (2006) also suggests that the greatest driver for reducing fuel lies in not the reduction of the direct costs of fuel itself, but the reduction of the attendant indirect costs of logistics to supply the fuel, the cost of fuel required to deliver the fuel needed, as well as enhancements in tactics that would accompany increased vehicular range, if fuel consumption were to be decreased on a given type of vehicle. Figure 7 displays the cost in 2006 that is associated with transporting fuel in Iraq to sustain Army training and contingency operations. Notice in Figure 7 that of the $13.68/gallon fuel costs, $11.33 or 82 percent of the total cost is attributed to support costs.

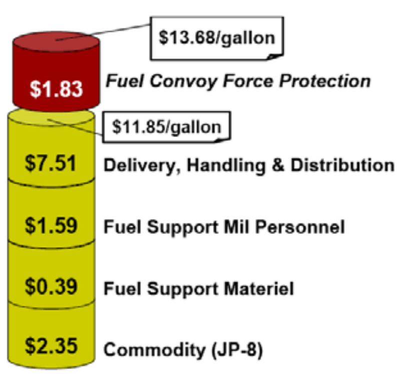

Figure 7. Fuel Handling and Support Costs [From: Army Installation Energy Security and Independence Conference].

To help clarify the enormous costs for one year, DESC Europe, in 2006, provided over 103 million gallons of JP-8, Diesel and MOGAS to northern Iraq utilizing 17,802 trucks which, if put end to end, would stretch from Washington, D.C. to Wilmington, Delaware[2] (DESC Factbook, 2006). Can DoD afford such high costs on a sustained basis[3]?

A study was conducted on the economic viability of a stand-alone solar photovoltaic system to a diesel-powered system in India in 2002. Kolhe, Kolhe, & Joshi (2002) decided that the only way to create fair analysis because their cost structures are entirely different was to examine the life-cycle costs of each to include: operational and maintenance costs, recurring and non-recurring costs, sensitivity to discount rates, diesel fuel costs, solar insulation, reliability, and solar array costs. In this analysis, the authors concluded that PV is the lower cost option at a daily energy demand of up to 15 kWh under unfavorable economic conditions, but up to 68 kWh with favorable economic conditions (Kolhe et al., 2002). To put this in perspective for DoD, a typical AC unit consumes about 3.5 kWh, so it could be more cost effective to run an AC unit (a niche application) for 20 hours using PV energy than diesel fuel. This is significant for DoD because AC units are often used to keep sensitive communications equipment cool at remote Forward Operating Bases (FOB). PV power would reduce the amount of reliance on liquid fuel transportation to the site. Trieb, Langni and Klai (1997) stated in an analysis of solar electricity generation, using different technologies, that for small and medium stand-alone applications, PV systems were the best choice.

In addition, Patel (2006) and Treib et al. (1997) suggest other major advantages of using PV power are:

- Short lead times to design, install and start up a new plant.
- Highly modular; hence, the plant economy is not strongly dependent on size.
- Power output matches very well with peak-load demands.

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2 Author's calculation: 103M gallons x \$13.68 (total ownership cost) = \$1.4B.

3 Another cost consideration that could be taken into account are the causalities service members sustain while conducting convoy operations and the medical care they would need. If these costs are factored in, the total ownership cost of \$1.4B will rise dramatically.

- Static structure, no moving parts; hence, no noise.
- Longer life with little maintenance because of no moving parts.
- Highly mobile and portable because of light weight.

These advantages may offer DoD areas of opportunity where fossil fuels, or other renewable energy technologies cannot. For example, in our current situation in Afghanistan, there are several FOBs throughout the country, which present logistical challenges for energy resupply. With the dynamic operational environment we face because there are no frontlines, FOBs can change to a different location at a moment's notice. Because PV is highly modular and mobile, it offers an easy, flexible power source for those remote locations. In addition, the silent operation of PV systems also can provide a unique opportunity for DoD to reduce its sound signature in remote locations, which can be key to maintaining a stealthy posture in hostile environments, especially in mountainous regions like Afghanistan where sound can be carried for quite a distance.

Finally, one of the most critical advantages that a PV power system provides is that there is little to no cost associated with maintaining the unit because there are little to no moving parts[4]. The effect of this is fairly significant on the supply chain both from an operational and a financial stand point. This means that operational units that take portable PV power systems into a theater will not require the extensive spare parts inventory support that accompanies other power systems. The direct effect on this is that operational units will not have to maintain inventories on site, thus allowing personnel to focus on the mission, rather than the maintenance of equipment.

2. Planning/Budgeting Process (PPBE)

The Planning, Programming, Budgeting, and Execution (PPBE) System is the primary tool used for defense resource management. PPBE's main purpose is to articulate the strategy to support the President's National Security Strategy and what

[4] Some PV power systems have moving parts such as systems that track the sun. These systems would require spare parts for motors. Military planners should have the option to select their desired PV power system to meet their operation requirements.

force structure, equipment and personnel is required to support it. The foundation for PPBE is the Future Years Defense Program (FYDP). This is a computerized data base with information on the force structure, personnel strength and financial picture of DoD which contains 11 years of data[5]. If DoD is serious about the use of solar power and decides to make it a priority, it will have a positive impact on the PPBE process.

a. Initial Costs and Long-Term Costs

Between 1980 and 2004, the capital cost of PV modules per watt of power capacity declined from more that $20 per watt to less than $4 per watt. During that same period, the cost of energy declined from almost $1 to less than 20 cents per kWh (Patel, 2006). So how does solar power compare with other energy sources on a cost per kWh? Bradford (2006), collected data and compared electricity production costs across common renewable and conventional energy sources (Figure 8) and concluded that solar power was more expensive at base electrical load, but much more competitive at peak and intermediate electrical loads, due to the nature of costs associated with shutting down and starting up conventional generators to deal with load fluctuations.

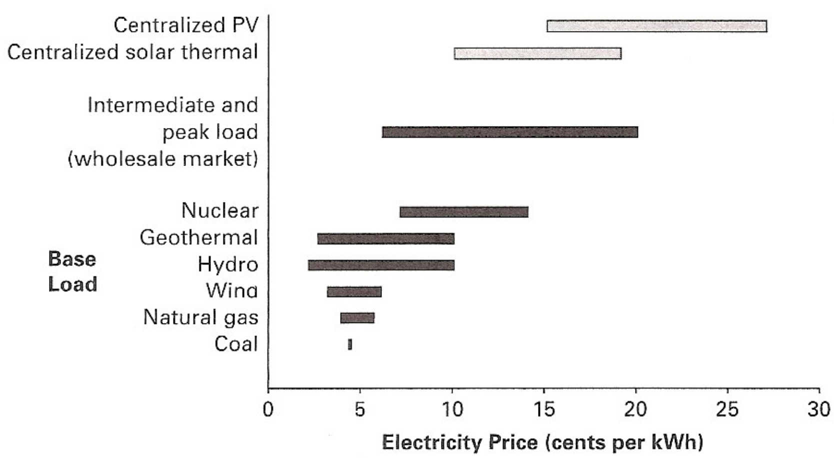

Figure 8. Cost comparison in kWh [From: Bradford]

5 The FYDP is broken into the following 11 years: The prior year (1st); the current year (2nd); two budget years (3&4); four out years (5-8); three additional years of force structure and manpower (9-11).

These costs, represented by horizontal "bars" considers the total lifecycle operating and maintenance costs of electricity generation, and carries uncertainties and assumptions about financing methods, generator life span, and fuel costs. However, Figure 9, the learning curve for solar power, shows a steep decline in cost projected into the future where it may eventually match the cheaper wind and biomass sources.

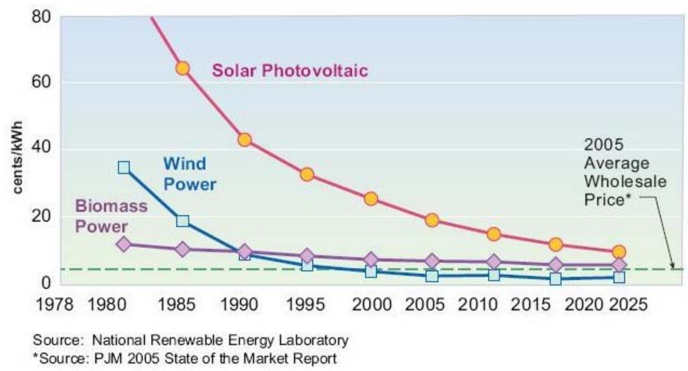

Figure 9. Renewable Energy Learning Curves [From: NREL].

This trend shows promise and is supported by the earlier remarks by the Prometheus Institute predicts that solar power costs will decrease 40 percent by 2010. Solar photovoltaic dramatic cost decrease has the potential to make it a solid contributor as one of the many instruments for DoD's long-term energy strategy. Could solar power surpass wind as a more cost effective energy source for DoD? According to Parker (2008), BTM Consult APS, a Danish wind power consultant, reported that land-based rotors have incurred a price increase of 1.38 million euros (2.13 million USD) per megawatt hour after rising 74 percent in the past three years. The high prices can be attributed to strong demand and the material costs increases mainly due to the increase in commodities that have pushed prices of steel, aluminum, and copper (Parker, 2008). As the cost of oil continues to rise to above $135 per barrel, solar power perhaps can now become more of a key instrument in DoD's energy portfolio for the future.

b. Solar vs. Wind: A Further Comparison

In 2006, Detronics Limited, a company in Ontario, Canada conducted a study with an objective to determine if a wind energy system or photovoltaic solar system was more cost effective. Detronics Limited used a Bergey XL.1 wind turbine system with a factory rating of 1,000 watts at a wind speed of 24.5 mph. The composite of the rest of the system was: a hub height at 100ft AGL; the tower was located 225ft from a 1,500 ah battery bank; and was connected with #2 gauge copper cable that was buried (Detronics Limited, 2006). For their PV system, they used 10 Shell SQ75 modules that were mounted on a fixed-axis, top post rack. To convert the incoming higher voltage to a system of 24 volts, they used an Outback MX-60 charge controller that was also connected with buried #2 gauge copper cable (Detronics Limited, 2006).

On an equipment comparison alone, wind was the cheaper option. Their wind system had a cost of $7,015, and the solar PV system cost $9,181.00. Two additional cost comparisons were conducted which were *purchase cost vs. cost per rated watts* and *purchase cost vs. cost per produced kWh.* In both of these cost comparisons, wind held the advantage. On a *purchase cost vs. cost per rated watts*, wind cost $7.02 per rated watt, while on a *purchase cost vs. cost per produced kWh*, wind cost $7.35. Solar on the other hand, cost $12.24 per rated watt on a *purchase cost vs. cost per rated watt* but only cost $10.68 when compared using *purchase cost vs. cost per produced kWh.*

Finally, Detronics Limited compared solar vs. wind using service life maintenance, seasonal and yearly variations, and design considerations. Their conclusion was that wind held a slight advantage over solar but that if they are used together, they can be a very reliable energy combination. In addition, they also acknowledged that solar can be more effective and cheaper than wind in certain niches. Endurance Wind Power (EWP) Inc. also came to the same conclusion. EWP stated in 2008, that the question should not be which renewable energy technology is better, but rather what is the most appropriate and affordable energy system for your location and application (niche or broad) (EWP, 2008). These conclusions from two independent organizations gives merit to our claim that solar power, while not yet the cheapest energy source, can still provide DoD more bang-for-the-buck in certain niches. The specific niches are analyzed and presented in Chapter IV.

c. Understanding Cost Estimate Disparities in Solar Power

Extensive research was conducted using government research agencies and companies involved in producing the same type PV systems in order to determine if there were any reports or data to suggest why there are disparities in cost per kilowatt hour[6]. Unfortunately, no such data could be found however, as we will find out below, data can be manipulated very easily to leverage an advantage against a competitor.

If the average person was presented with 10 different companies who make photovoltaic solar cells using the same technology, and each company only provided their cost per kilowatt hour, would the average person be able to make the decision as to which one is the best? According to Newick (n.d.) in order to make this decision, a buyer would need to know three things. First, is how much does the system cost including all rebates and tax credits? Second, how much energy can the solar system generate (forecasting can provide an accurate estimate)? Finally, what is the size of the system? The formula to compute the cost per kilowatt hour in simplistic terms is: *Investment / Energy * Size * Years.* For example, a system costing $25,000 with a yearly energy output of 2,000 kilowatt per hour (kWh), a system size of 3 kW, and a life span of 30 years, costs $.14 cost per kWh as computed from the following:

$25,000 / 2,000 kWh * 3kW * 30 years = $.14 per kWh.

So why are there cost disparities and disagreements in solar power and among all renewable technologies for that matter? Let's examine this referring to the equation above. If any one number is changed, it changes the result. Similar equations are used to determine the cost for other energy generation technologies but are beyond the scope of this report. So, if two identical companies used the same data given above, but one company claimed that the life expectancy was 35 years instead of 30 years it results in a new cost per kilowatt hour of $.12 kWh. In this instance, data manipulation, whether intentional or unintentional, can cause cost estimates to vary which can confuse a

6 The website http://www.enf.cn/database/panels-usa.html was used to locate 40 US companies that manufactured PV systems. To make sure that the research was consistent, we examined only companies that used Amorphus panel technology. Searching their websites resulted in no concrete data for cost per kilowatt hour. The companies were vague and only noted their "low cost per kilowatt hour" technology.

decision maker or investor. Also, it is helpful to consider the problem that arises in the investment portion of the equation. Companies are continually looking to improve business practices and reduce costs, which could lead to a lower capital cost assumption on the investment side of the equation, and reduce the cost per kilowatt hour.

The bottom line is that the only way to get consensus on renewable energy production costs is to ensure that the exact same variable values are used. But due to diversity, biases, and preconceived notions it would be unlikely to get exactly the same result across all those who make the estimates. This has certainly been a finding during the research for this report, with disagreement among energy enthusiasts about which renewable energy offers the “best” cost solution.

D. SUMMARY

Even though solar power is not yet the most cost effective or efficient on a large scale, solar power’s continued trend towards better efficiency and low cost are making it more attractive to become a significant factor in a long term DoD energy portfolio. One of solar power’s strengths is its small supply chain which can make it very attractive for DoD, especially in remote operating environments like the ones we currently face in Iraq and Afghanistan. This small supply chain can help reduce the infrastructure costs associated with other traditional energy sources. Finally, it appears the main reasons that there exist disparities in solar power cost computations is because of preconceived notions, biases and use of different variables in estimating costs.

IV. UNCERTAINTY AND DOD ROLE IN DIFFUSION

A. INTRODUCTION

Fifty-eight years ago, in 1950, under the very real threat of global annihilation amid an intensifying American-Soviet cold war conflict, The Truman administration issued a key policy document, National Security Council Report 68 (NSC-68) which issued an urgent challenge to adopt an offensive strategy to defeat the Soviet Empire. American strategy, according to NSC-68, aimed to “induce a retraction of the Kremlin’s control and influence,” and to “foster the seeds of destruction within the Soviet system” (Sempa, 2004). NSC-68 was an important part of an overall shift in American foreign policy to a comprehensive containment strategy that was perpetuated to varying degrees by successive administrations, and eventually redefined into a more aggressive “we win, they lose” strategy by Ronald Reagan. The containment strategy, and even more so, Reagan’s strategy was successful in exploiting the vulnerabilities of the Soviet Union and bringing about its collapse in December 1991.

President Truman and President Reagan gave the United States a vision of a future it could create. From their strategies the U.S. Government, allied governments, academia, and industry worked together for fifty years to convert an unprecedented challenge into many small victories and eventually a total win. Did the U.S. strategy against the Soviet Union remain the same throughout the half-century conflict? It certainly did not; but this is not essential for long-term strategies. Good strategies must be internally consistent but must also be adaptive to the changing environment and future uncertainties.

The methodology for forming a long-term strategy requires considering the desired end state and stepping backward in time toward the present to identify the hierarchy of events that must be met to support subsequent achievements (Hornitschek, 2006). Before improved solar energy capabilities can be realized, certain technological challenges must be solved, i.e., storage, transmission, electricity output, etc., and before that, certain research and development institutions must be formed and resourced as well as strategic partnerships with industry and academia. In this manner, a series of milestones is identified to serve as short term wins, just as in the case of defeating the Soviet Union, or putting the first man on the moon. Kotter (2007) states these short-term wins are essential for sustaining the transformation process. In the context of creating a future all-solar and electric-powered military force, two basic strategies shall be considered:

- Allow market forces and timing to create and deliver necessary technology diffusion and transformational capabilities with DoD taking a reactive role
- DoD takes a proactive role in leading an energy transformation much as it did in the space race with NASA (Hornitschek, 2006), through diminishing solar technology uncertainty, impacting experience curve and scale effects, and driving diffusion of solar energy applications.

With the unique acquisition lead times, government financing rates, long-term focus and logistics infrastructure of DoD, this chapter intends to defend the latter strategy by delving deeper into the characteristics of technology uncertainty, effects of complementary technologies, and DoD strategy options for driving diffusion of solar power.

B. TECHNOLOGICAL INNOVATION UNCERTAINTY

1. Nature of Uncertainty

In order for a powerful complex organization like DoD to positively influence diffusion and learning of a new technological innovation, it should understand the sources and effects of innovation uncertainty. That is not to say that any organization has the ability to anticipate the full future impact of successful innovations. Most technology forecasts fail because uncertainties stand in the way of full exploitation and the diffusion paths depend on so many uncontrollable factors. There are endless cases throughout history where man has been unable, despite best attempts, to predict full development impact, even after technical feasibility of new inventions has been established. The reason it’s difficult to foresee the uses of a new technology is that most major inventions originate in a very primitive form in an attempt to solve very specific and narrowly defined problems. Often, its eventual use emerges to have major impacts in totally unanticipated contexts (Rosenberg, 1996). The steam engine, for example, was invented in the eighteenth century specifically for pumping water out of flooded mines. It underwent improvements and later became essential as a source of power for textile factories and iron mills, then as a source of power for transportation, then on for generating electricity. Similarly, Marconi's radio invention satisfied the primary need for communicating between two points as in ship-to-ship or ship-to-shore, and not for broadcasting to wide public audiences (Rosenberg, 1996). Patent lawyers at Bell Labs passed on a patent for their development of the laser because they thought it had no use in future relevance on the telephone industry. Looking back, perhaps no other invention has had more impact on telecommunications, along with fiber-optics, than the laser (Rosenberg, 1995). Rosenberg (1995) points out that about 80 percent of R&D expenditures are devoted to improving products that already exist, rather than inventing new ones. A familiar example is the telephone, which has undergone incredible improvements during its hundred-year life, enhanced by going cordless, cellular, voicemail, and so on. This paper suggests that DoD, along with commercial industry, devote R&D to multiple solar technology paths of improvement.

2. Dimensions of Uncertainty

Besides the basic question: "Will it work?" Rosenberg (1996) suggests that uncertainty is the product of several sources and that understanding the nature of these sources and the barriers to overcoming them goes to the heart of how new technologies are devised, how rapidly they diffuse, the extent of that diffusion, and the eventual impact on economic performance and welfare.

a. Potential Uses

First, when a new technology is developed, it is difficult for industry to fully identify all its potential uses and improvements. Well before the development of the first official photovoltaic cell in 1954 (Bradford, 2006) by researchers at Bell Labs, the basic PV effect was first recorded in 1839 by Edmund Becquerel (Hubbard, 1989) and, like the first steam engine, no one could anticipate the future advances and applications that lay ahead. Even in the 1950s and 1960s, PV cells were limited to applications in U.S. satellites and spacecraft. It was not until the oil crisis in 1973 that terrestrial uses of PV were considered and technological efficiency took off. The jump from niche applications in the 1960s to broad applications in the 1970s and decades afterwards set the stage for accelerated diffusion, but there's a considerable way to go. Newer solar technologies like solar thermal and thin film carry the same unanticipated future applications and improvements.

b. Complementary Innovations

A second dimension of uncertainty comes not from the technology as mentioned above but from improvements that take place in complementary technologies. One notion is that the creation of invention A increases demand for invention B. On the other hand, the creation of invention A can also kill off invention B. Sometimes, the success of invention A depends on invention B, and invention B does not exist yet. This complex relationship is overly simplified of course. Rosenberg (1995) suggests that technological systems should be thought of as comprised of clusters of complementary inventions and that performance improvements in one part are of only limited significance without simultaneous improvements in other parts. Bell Labs would have had to anticipate the future invention of fiber-optic technology to see the relevance of the laser in the telephone industry.

It is not uncommon for the invention of a new technology (invention A) in a highly competitive society to lead to an accelerated improvement of an older technology (invention b) (Rosenberg, 1995). For example, in the 1940s, predictions of future applications of computers were very pessimistic. They filled an entire room and contained thousands of electron tubes, just to perform basic mathematical functions. When transistors and then integrated circuits were invented, they turned out to be catalysts for enormous growth and applicability of the computer industry, beyond which no one had previously imagined.

Sometimes, complementary technologies may be exactly what are needed to spawn an entirely new system as in the case of the electric automobile. Regenerative breaking, flywheel technology, and battery development are among the many distinct complementary technologies that are traveling unique paths of uncertain development and applicability. However, they have all progressed far enough to become integrated into a system that may likely have a promising future. Rosenberg (1995) cites a brilliant example in which Sony's development of the Walkman used existing technological capabilities (involving batteries, magnetic tapes, and earphones) to combine into an entirely new product that could provide entertainment in a way no one had previously thought of.

It is important to note that innovation of systems can only progress as fast as the slowest developing complementary technology. Arguably, the weakest complementary technology in the electric car "cluster" is the rechargeable battery pack and its ability to quickly charge and store enough energy to be practical and cost efficient. Giant leaps have been made over the past decade however and the 2008 Tesla Roadster, now in production at the time of this writing, is making headlines across all media channels.

It is also conceivable that old technologies awaiting complementary inventions will become substituted by the new technology, even when predictions for the original technology pointed to enormous promise. Rosenberg (1996) illustrates that communications satellites unexpectedly declined during the 1980s with the introduction of fiber optics and the huge and reliable expansion of bandwidth capacity that they brought with them.

To summarize, the simultaneous advancements in old and new technologies, along with the dynamics of substitutes and complements creates challenging barriers that prevents decision makers from understanding the total effect of uncertainty on technological innovation. For the DoD in particular, this environment requires considerable analysis and sequential decision making approaches in order to minimize risk and costly failures associated with renewable energy development and diffusion.

c. Value and Economic Feasibility

In order for market forces to create and deliver necessary technology and diffusion of technologies, there must be certain human needs met. If the technology doesn't save time, save money, or add value anywhere along the value chain, it will be very difficult to realize a promising future without external intervention such as subsidies, taxation of substitutes, or others. Moreover, systems must be economically feasible. The Concorde supersonic jetliner was a marvelous success technologically, but was a financial disaster costing British and French taxpayers billions of dollars (Rosenberg, 1995). As solar energy technology becomes more competitive with fossil fuel prices, and as diffusion drives down capital costs, its value and economic feasibility will likely improve and become more relevant to the research community and society.

3. Uncertainty and Decision Making

In the private sector, researchers are expected to spend their research and development funds on pathways they hope will turn out relevant economically and socially. Thus, market forces encourage exploration across a wide array of alterative paths. It is essential, especially in the early stages when uncertainty is high, to diversify in this manner and take limited sequential approaches to decision making (Rosenberg, 1996). The enormous risk of failure demands this approach, or else premature commitment ensues and likely leads to failure. It would be difficult to find a better illustration of survival in an environment of immense uncertainty than in the pharmaceutical industry. Drug makers are required to thrive with 99 percent failure rates, pursuing thousands of sequential pathways, just to find one successful drug that makes it to market. Statistics show that it takes an average of 12 years for an experimental drug to travel from the lab to the consumer, and that just a little over one percent of all experimental drugs make it to human testing. Of that total, only 20 percent get actual Food and Drug Administration (FDA) approval (Lipsky & Sharp, 2001). The point is the pharmaceutical industry has learned to deal with this uncertainty and get products out to consumers. It could be argued that if uncertainty in the pharmaceutical industry was mitigated somehow, perhaps failure rates would drop along with cost to the consumer.

The same holds true in the solar energy field. As it matures, market forces will spawn increasing imitators and diffusers and reduce uncertainty and indecision.

Government organizations like DoD are not quite on the same level of playing field as private industry when it comes to dealing with technology uncertainty. The tremendous lead times to adjust force structure, systems and doctrine may prevent DoD from waiting for market forces to shape an energy future. While DoD is waiting, it is absorbing more and more risk that petroleum supplies will become a critical concern and national security will be compromised. Additionally, U.S. government agencies like DoD have historically been able to absorb more uncertainty risk and champion or concentrate focus on narrow fields of technology, neglecting alternatives, as opposed to taking a cautious, more diversified sequential approach that private industry practices. These wasteful premature commitments have led to poor decisions and poor financial efficiency. The U.S. government's post-war energy policy was not wrong simply because it made a major commitment to nuclear power that subsequently turned out to be problem ridden, but because it was so single-minded and neglected many alternatives, including improvements in efficiency as well as new energy sources (Rosenberg, 1995). There are ongoing debates regarding the state of the current DoD Joint Strike Fighter and Littoral Combat Ship programs on whether DoD neglected alternatives, and rushed to decisions that are now creating enormous cost overruns, schedule slips and threats of program cancellation (in the case of LCS). To deal with the uncertainty of solar energy technology, and all renewable energy technology as a whole, DoD should learn from the private firms and resist temptation to champion any one technological alternative and manage a more diversified research and development portfolio with a broad range of alternatives in case social or economic priorities change.

C. TECHNOLOGY DIFFUSION

Diffusion is the process by which technology is dispersed throughout society and adapted for widespread use (Sawin, 2001). According to U.S. Government Accountability Office (GAO), it takes on average 15 to 20 years for major technologies to be diffused throughout the economy. However, the GAO studies also revealed that the current technology used for generating electricity took more than 50 years to diffuse due to inertia and infrastructure of old systems. The literature on diffusion depicts the classic “S” shaped curve below in Figure 10.

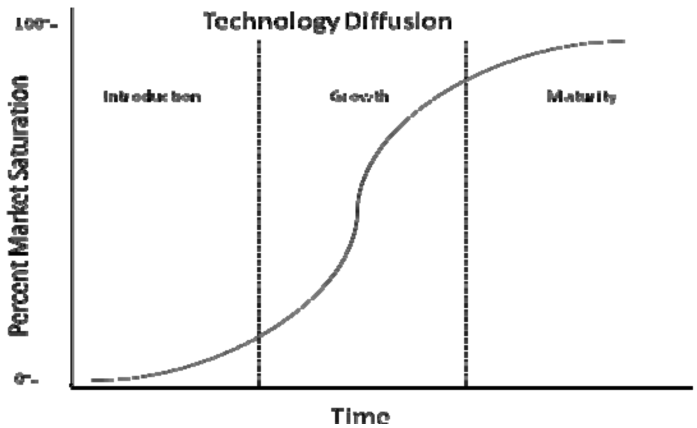

Figure 10.   Diffusion of Technology Curve [After: Rosenberg].

When a technology is first introduced, it requires considerable effort and funding to break into the market. This phase is characterized by a great deal of risk during much research, development, and experimentation. If barriers are overcome, a technology will enter a phase of accelerated growth in which viability and usefulness of the technology has been established, standardization increases, and prices drop due to economies of scale. Finally, a technology will enter a phase in which improvements face diminishing returns and market saturation sets in. In this maturity phase, competition is based more on cost reduction rather than design improvements. What is not illustrated is a post-maturity phase in which a technology declines. This occurs due to obsolescence caused by substitution, or changes in economic or social priorities.

A key reason for slow diffusion of technologies as discovered in the GAO report is that basic technological problems have to be resolved before society embraces them (Goldfarb, 2005). To support this argument, it is helpful to examine a case involving urban transit, in particular, the electric street railway system. When the electric transit technology was introduced in the 1830s, its adoption was inhibited by a key technological barrier – electricity was supplied by messy liquid filled batteries. For forty years, experimentation continued with little progress until a complementary technology came along. Known as the dynamo, an electric generator that converted rotational energy into direct current (DC) electricity was invented in the late 1870s (Goldfarb, 2005). By this time, electric driven transportation was looking more and more attractive due to a diseased ravaged horse population in the eastern U.S.; noise, pollution and safety issues associated with steam street cars; and the costliness of cable cars (when cables were under the street). However, according to Goldfarb (2005), there were three distinct challenges: distributing electric power from a generator to a moving vehicle, designing a motor that could function under varying loads without severe sparking and brush wear, and devising a method to transfer the power from the motor to the wheels. At this point, the electric street car was in the "introduction" phase of diffusion. Over the course of the 1880s, a series of ventures of various entrepreneurial inventors found solutions to all three problems and the electric rail car entered a phase of dramatic market growth. From 1880 to 1903, the total length of street electric railways increased thirty-fold from 1,000 miles to 30,000 miles (Goldfarb, 2005).

There are countless instances throughout history similar to the electric streetcar case where social and economic factors played a large role in the rate of diffusion of new technological innovations. Before discussing what policies and actions an organization like DoD can champion in order to speed the rate of diffusion of solar energy technology, it is important to introduce the popular diffusion frameworks contained in the diffusion literature. The diffusion framework is a complex one of several sub-theories or concepts that provide insight into human and social nature, including how new information is accepted (or not accepted) by potential users. Sub-theories of the classic diffusion framework include the innovation-decision theory, the individual innovativeness theory, the theory of rate of adoption, and the theory of perceived attributes (Rogers, 2003). Only the theory of perceived attributes will be discussed in this report because it is the most relevant to adoption of technology by society, and not to the practice of individuals.

1. Theory of Perceived Attributes

According to Rogers (2003), the theory of perceived attributes focuses on how the technology participant views characteristics of the practice and actions under investigation. These affect the rate of diffusion and have been typically characterized as those that relate to complexity, compatibility, relative advantage, observability, and trialability. Complexity refers to the degree of difficulty of understanding and implementing the technology from the perspective of a potential adopter. Compatibility relates to the degree to which the practice is compatible to current objectives and philosophies of society. Compatibility factors can be values or something as simple as not having the right resources (land, financing) to implement the practice. Relative advantage concerns itself with the possibility of increased savings, reduced cost, or other economic and social factors that make adoption more advantageous over other alternatives, including doing nothing. Observability speaks to the visibility of results of the implemented practice. Some practices are obviously more observable than others (cleaner air, reduced environmental noise, and construction of solar facilities vs. preparing a conservation plan, for example) and therefore might be adopted more quickly. Finally, trialability deals with the potential to experiment with the technology on a smaller, less extensive scale. The hopeful outcome is that a potential adopter can implement the new practice on a trial basis and then modify it further to meet specific needs. In general, diffusion can be driven by a top down approach from the experts to users, or a centralized approach where wide sharing of power and control among clients is practiced (Sawin, 2001).

2. DoD Options for Driving Diffusion

Sawin (2001), suggests that industrial and financial sectors are short-term focused and that private firms will not invest in large volumes of commercially available renewable energy technologies at the current prices and levels of risk. Driving diffusion of solar energy technology will have a positive influence on the attributes mentioned above and on costs and economies of scale. Driving diffusion also stimulates the "learning" or "experience curve" of new technologies. Learning theory simply states that as cumulative production of a technology doubles, its cost declines by a constant percentage. This percentage has been termed "progress ratio" or "slope of the learning curve" by the literature (Poponi, 2003). There have been numerous studies conducted on the historical learning curve slope for solar PV technology. Poponi (2003) compares several studies conducted by researchers and confirms with his own analysis that the slope of learning for PV technology from 1976 to 2002 has been on an 80 percent trend. This indicates that costs have reduced by 20 percent at every doubling of cumulative production. Thus, the aim should be to drive diffusion such that learning curve slope trends away from 80 percent to something smaller. Driving diffusion and stimulating learning can be accomplished by contributing to both the supply and demand sides of the solar energy market.

a. Instruments to Develop Solar Energy Technology: Supply Push

Supply-side options include R&D policies devoted to improving the reliability, durability, and efficiency of a technology, and to reducing its cost (Sawin, 2001). R&D programs foster the creation of new technologies that can create positive impacts over the long term. Since DoD is not in a position to directly manufacture solar energy equipment, the logical approach is to increasingly channel resources into solar energy R&D, not just for PV, solar thermal, thin film PV, etc., but for essential complementary technologies such as batteries, microturbines and thermal storage. In general, only large industries and governments have the resources and interest to conduct R&D (Watson, et al., 1996). DoD research agencies like DARPA, and Army CERL are already contributing essential R&D to the field of Solar Energy.

Research and Development activities fall into three broad categories: basic research, designed to advance scientific knowledge of an energy technology; development of new technologies and new energy sources for commercial application; and improvement of existing technologies (Sawin, 2001). The intention is for these activities to support R&D that the private sector would not undertake. The returns from learning and R&D are uncertain, and risks are high but the results can be potentially large (Rosenberg, 1996), therefore the best strategy is to make gradual cautious investments and to pursue gradual technological experimentation. Similarly, the Intergovernmental Panel on Climate Change (IPCC) noted that "…it is important to have a government strategy that does not attempt to pick individual technology winners." This is why again this report recognizes the merits of wind and geothermal energy and growth and development in those fields. These technologies should remain as part of a diversified

DoD energy portfolio, and efforts should also be diversified across a portfolio of specific technologies and niche applications within the solar energy field itself.

Watanabe (1995) found that government R&D stimulates industrial R&D, thereby increasing what he termed "technology knowledge stock." This knowledge stock leads to cost and performance improvements, which stimulate demand, increasing size of niche markets which lead to economies of scale. This also increases learning possibilities and therefore further cost reductions, which in turn feed back as further stimuli for industrial R&D and technology improvements. His study also found that there is a time lag between R&D expenditures and returns (improved technology performance and lower costs) of less than 3 years.

Since DoD would likely conduct R&D in areas that the public sector likely would not risk, a method should be considered to join the R&D findings and accomplishments of DoD and the private sector. Sawin, (2001) suggests that such public R&D must be done in cooperation with the private sector, and that "it seldom makes sense to support research and development with public funds to the point of commercial readiness and then attempt to transfer the technology to a commercial developer. The organizational learning involved in research and development is difficult to transfer. It is far better to develop technologies in collaborative efforts involving research institutions, private equipment developers, and potential users, thereby promoting learning simultaneously in the laboratory, factory, and field." Referring back to the theory of perceived attributes, increased R&D in partnership with private sector leaders, may contribute significantly to reduced complexity of solar technology, greater understanding and compatibility, and greater relative advantage.

b. Policies to Diffuse Solar Energy Technology: Demand Pull

Demand side options complement supply side and further contribute to diffusion. There are many more options for DoD to affect market demand than supply. There seems to be three schools of thought about the types of demand policies that are most effective in advancing new energy technologies. One focuses on regulations, one on subsidies, and the third believes that both are essential (Sawin, 2001).

So which types of demand side policies are most effective? According to the EIA, “It is regulation and not subsidization that has the greatest impact on energy markets.” Also, while regulation burdens some producers or consumers with costs, it provides benefits to others and does not require government funding due to loss of revenue (EIA, 1992). In contrast, the California Energy Commission (CEC) argues that regulations, collaborative programs and other low-cost activities that address market barriers are not as effective as subsidization in the form of high-cost tax incentives and standard offer contracts in accelerating the market adoption of new technologies. This is because the latter policy types “create an early large market for consumers which can create production economies to further reduce costs.” The CEC report goes on to state that “These successful activities are an important reason why California is now the world's leader in energy technology development (California Energy Commission [CEC], 1996).” Although subsidies are generally effective in the short term, they are not effective long term solutions for some programs. If a subsidy is very large, it can create an industry that is costly and highly dependent upon that subsidy. Subsidies can attract entrepreneurs who have short-term interest in the subsidized industry, and who make minimal investment and buy out as much of the inputs as possible, reducing ultimate quality (Sawin, 2001).

Whether its subsidization or regulation or both that is most effective, DoD is not in a position to issue subsidies or tax incentives to itself or the public, however, in essence DoD is able to indirectly subsidize the solar technology industry by driving diffusion via four powerful pathways: Goal setting, solar resource studies, government purchase contracts, and education and information.

The federal government set one of its first renewable energy goals with the passing of executive order 13123 in June, 1999. Section 204 of the order states that “each agency shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects, and by purchasing electricity from renewable energy sources.” Six years later, the Energy Policy Act of 2005 set more specific federal goals for renewable energy adoption calling for three percent of energy purchases from renewable sources during 2007 to 2009, five percent from 2010 to 2012, and 7.5 percent from 2013 and beyond. Hoping to become a key proving ground, the DoD followed this up with a more aggressive goal of 25 percent renewable energy use or purchase by the year 2025 (Hornitschek, 2006). Figure 11 shows the progress DoD reported to congress in 2005. The trend indicates that they are on target to meet or exceed this goal and a recommendation might be to adjust the goal higher to something more difficult to attain, such as 30 percent by 2025, or to implement solar energy systems across all 5,300 DoD sites. It would cement DoD's leadership in the renewable energy landscape.

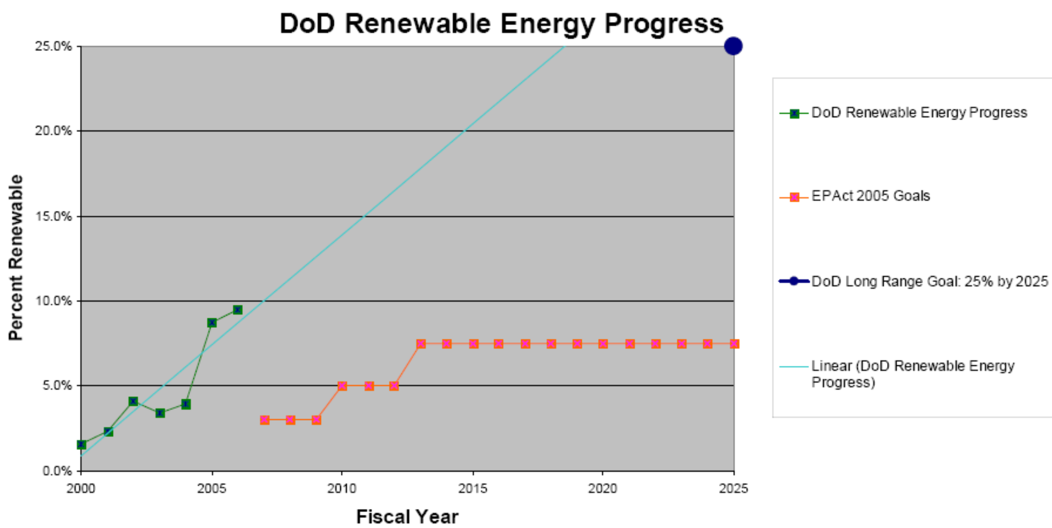

Figure 11. DoD Renewable Energy Progress Since 2000 [From: DUSD(I&E)].

This leads to the next strategy DoD might want to consider or improve upon, and that is Solar resource studies. DoD should partner with universities and scientific organizations to create siting maps to delineate the best solar areas in the U.S. and abroad against current and future military installations. These solar energy production maps should be made publically available and shared with other research firms and technology producers. There are many siting maps in existence today already, but the new studies could verify and improve on those already performed, using the latest efficiency attributes of cutting edge solar energy systems of today and tomorrow. It will become a vital preliminary step in preparing to implement solar energy applications across all DoD sites.

Purchasing strategies will likely become the most powerful driver for DoD to push diffusion and drive adoption along the "S" curve. This strategy can be executed in several different ways. For example, DoD could dedicate resources to up-and-coming speculative technologies like the latest generation thin film applications, or toward mature solar technologies like solar hot water heating or photovoltaic cells. Purchases and investments in new, immature technologies may have the tendency to benefit the survivability and acceptability of the technologies and the companies producing them. Economically speaking, this can be an important driver for healthy competitiveness and innovation under strong demand. Today, DoD faces a shrinking industrial base of contractors with the capabilities necessary to field major shipbuilding and weapons system projects. One can argue that this shrinkage may have something to do with the fact that the largest DoD procurement contracts often go to tried-and-true companies like Lockheed Martin and General Dynamics and not so much to less mature, untested companies.

Another way DoD purchases can be broadly characterized is whether it's applied niche by niche, or installation by installation. For example, by going niche by niche, DoD can set out to place grid-connected PV modules on all rooftops, thereby driving this particular niche into greater adoption through it's diffusion, then move on to another niche such as installing off-grid solar thermal systems with microturbines. Or, by going from installation to installation, DoD can utilize the best of all solar technologies depending on siting characteristics, installation needs, agreements with utilities, etc. Each strategy has its merits and implementing systems nice by niche would likely enhance the perceived attributes of observability and relative advantage more quickly than going installation by installation. On the contrary, moving from installation to installation and employing a variety of solar technologies based on the best fit, would likely reduce the perceived attribute of complexity and increase the trialability attribute.

According to the office of Deputy Under Secretary of Defense for Installations and Environment, DoD currently owns 2.4 billion square feet of real property, over 343,000 buildings, and 32 million acres of land. Placing rooftop PV cells on 343,000 buildings would make an enormous impact on the demand market for solar cells and drive down cost while driving up adoption.

There is a way to put this impact in perspective. Using a conservative estimate for PV electricity generation of 10 watts per square foot (EERE, 2007), 8 hours of daily sunshine, and an assumption that 50 percent of DoD's rooftops could accept PV panels, approximately 120 trillion British Thermal Units (BTU) of electricity would be produced in one year. According to EIA (2006), the total solar/PV energy produced in the U.S. in 2006 was 100 trillion BTU. The conclusion is that PV arrays covering half of the rooftops owned by DoD would match all of the other PV energy generated in the U.S. over the same time period. An even more shocking comparison results from a solar thermal energy analysis. If only 10 percent of the land owned by DoD were covered with solar thermal energy plants, under the conservative estimates of 3.6 acres per MW (EERE, 2007) and 8 hours of daily sunlight, 8 quadrillion BTU of energy would be produced in one year. The total of all renewable energy produced in the U.S. (solar, wind, geothermal, hydroelectric, biofuels, etc.) in 2006 was 6.9 quadrillion BTU (EIA, 2006).

Historically, DoD has benefited more from wind energy production than solar when considering the number of projects completed and the energy output realized. However, it is interesting that there have been many more solar projects fielded by the Department overall. Despite this, wind energy generation and solar energy generation in DoD was nearly equal at 11,000 MWh in 2007. (DoD, 2008). Table 1 below illustrates an upward trend in the number of solar and wind projects in DoD from 2003 to 2007. The fact that the average MWh per project for wind was approximately 5 to 10 times higher than the average MWh produced per solar project indicates that wind has been reserved for larger energy applications, and solar for smaller, niche applications.

	2003	2004	2005	2006	2007
Number of DoD Solar & Wind Projects					
Solar	27	76	87	106	77
Wind	2	2	8	10	12
Total MWH for DoD Solar & Wind Projects					
Solar	3220	8855	6638	8689	11666
Wind	1123	1205	8592	15810	11358
Average MWH per DoD Solar & Wind Project					
Solar	119	117	76	82	152
Wind	562	603	1074	1581	947

Table 1. Annual DoD Wind and Solar Projects Density [After: DoD].

Figure 12 represents the same data in graphical form, showing solar and wind projects in DoD increasing since 2003, and the difference in the number of projects overall for both. Figure 13 illustrates the "energy production density" for wind and solar as mentioned above. Again, this confirms the intuitive reasoning that DoD is using wind energy for large production and solar for niche applications generally.

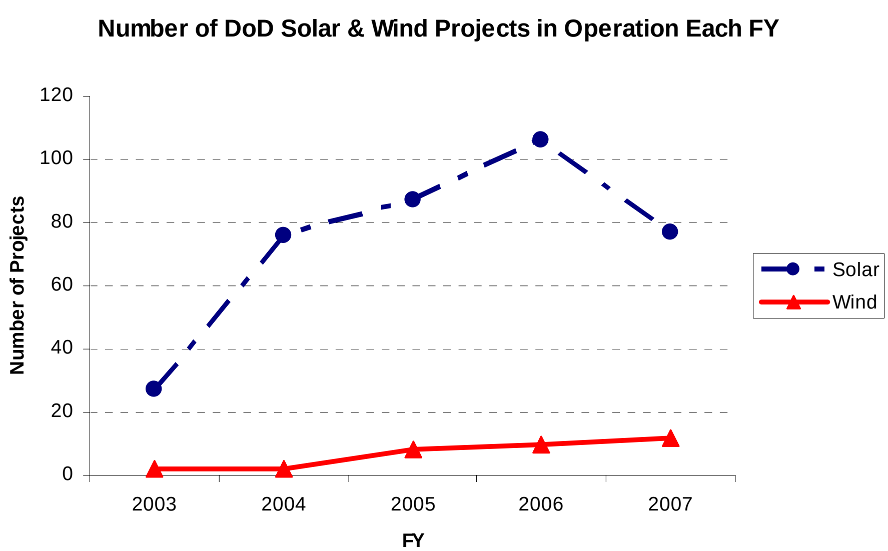

Figure 12. DoD Solar and Wind Projects in Operation Each FY [After: DoD].

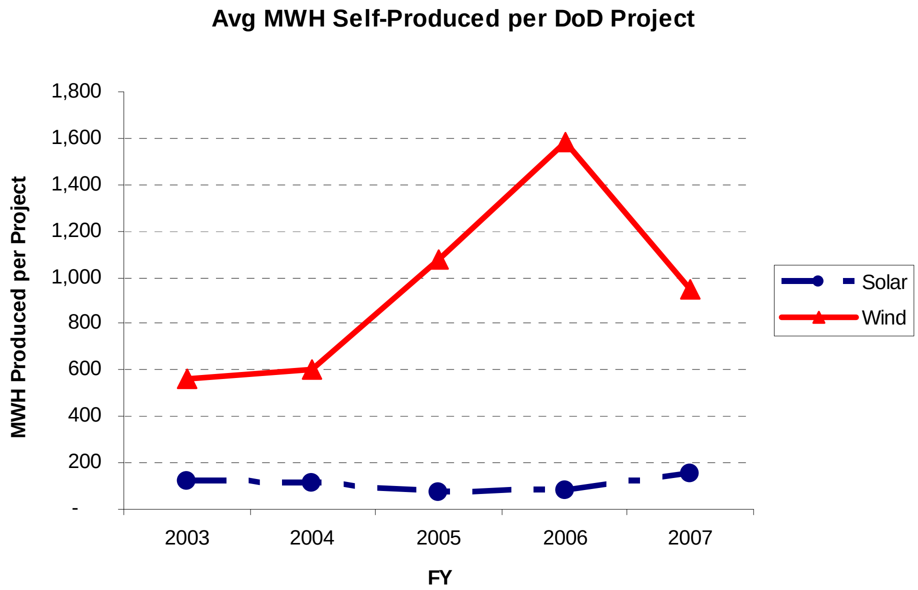

Figure 13. Density of Solar and Wind Generated per Project [After: DoD].

Further study of solar project trends and activities in DoD also produced a list of a number of prevalent niche applications that have proven successful and cost effective for DoD. Table 2 shows these most common niche applications already in use as well as speculative future thin film applications likely to be deployed as the technology matures (except for thin film shingles which are already in use on a few DoD buildings). It is the recommendation of this report that thin film niche applications such as these be tested and assessed in the field in the near future. Additionally, solar thermal energy is another application that has not yet been employed by DoD, and is listed in the table as a recommendation for future consideration. Overall, Table 2 represents a diversified portfolio of solar niche applications that have been beneficial to date or are expected to be beneficial in the near future.

Technology	Niche Application
Solar Walls (Trombe Wall)	Buildings, Hangars & Barracks
Solar Domestic Hot Water Heating	Buildings, Housing & Barracks
Solar Domestic Hot Water Heating	Swimming Pool Heaters
Photovoltaics	Rooftop Electricity Generation
Photovoltaics	Air Traffic Control Towers
Photovoltaics	Terrestrial Power Plants
Photovoltaics	Airstrip Lighting
Photovoltaics	General Exterior Lighting
Photovoltaics	Range Markers & Targets
Photovoltaics	Traffic Lights
Photovoltaics	Windsock Illumination
Photovoltaics	Outdoor Security & Warning System
Photovoltaics	Refrigeration and Cooling
Photovoltaics	Remote Alarms & Indicators
Photovoltaics	Remote Radio Equipment
Photovoltaics	Remote Water Pumping Stations
Photovoltaics	Satellites
Photovoltaics	Space Heating
Photovoltaics	Weather Data Equipment
Solar Thin Film	Automobiles
Solar Thin Film	Backpacks & Sacks
Solar Thin Film	Battery Chargers
Solar Thin Film	Cell Phones
Solar Thin Film	Notebook Computers
Solar Thin Film	Roofing Shingles
Solar Thin Film	Tent Material
Solar Thin Film	Tinted Windows
Solar Thin Film	Uniforms
Solar Thermal Energy	Terrestrial Power Plant
Solar Thermal Energy	Solar Cookers

Table 2.

Table 3. DoD Proposed and Existing Solar Niche Applications [After: DoD].

When considering purchasing strategies among a portfolio of niche solar applications, several factors should be weighed including mobility and deployability of the equipment, production efficiency (energy produced per amount of material used), production capability (ability to support very large demand applications), and cost efficiency. Certainly other characteristics can be included for analysis but for the sake of qualitatively assigning value to each solar technology, this will suffice. Figure 14 represents each technology's relative value in relation to each other. For example, solar thermal energy is more cost efficient than PV, but is much more difficult to mobilize and deploy in the battlefield.

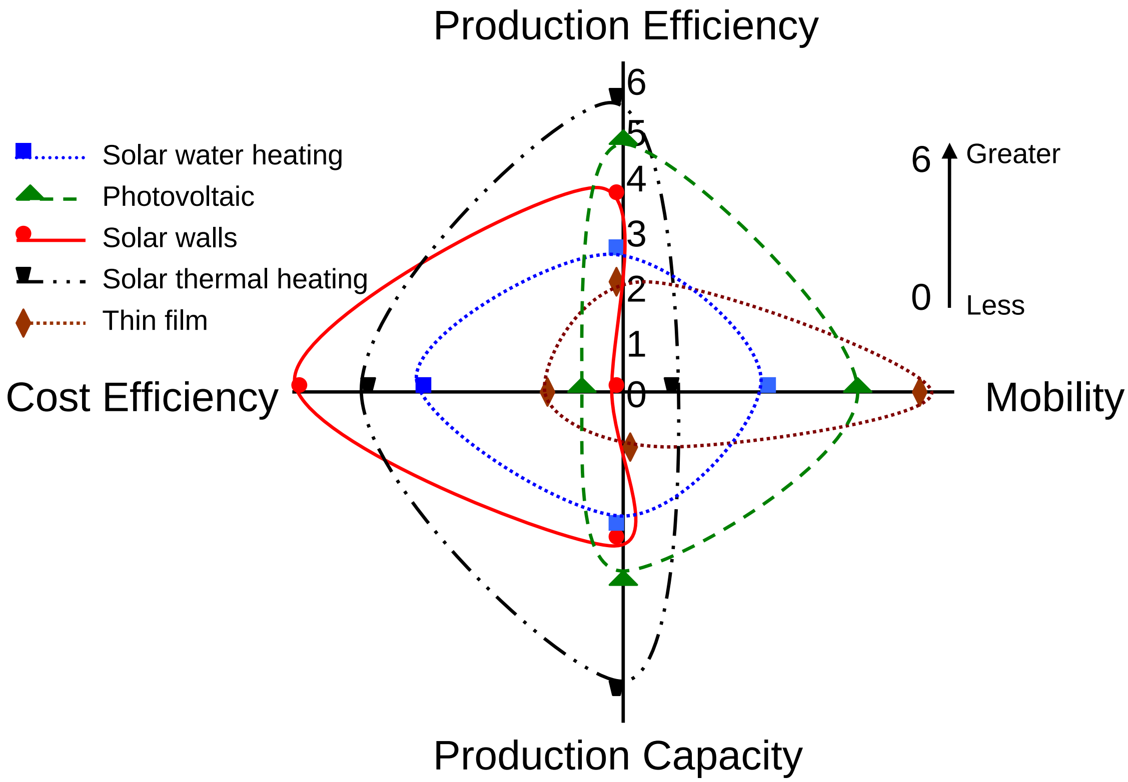

Figure 14. Solar Technology Niche Value Constellation

The most important reason this project argues why DoD can be a substantial trend setter in this industry is the contracting power it has. All federal agencies have the options of using financed contracts or funded contracts, or both. Legislation enacted in 1992 created Energy Savings Performance Contracts (ESPC), which are contracting vehicles that allow agencies to fund energy projects without up front capital costs and without special congressional appropriations (EERE, 2007). ESPCs are awarded by DOE and are financed contracts in partnership with energy service companies (ESCO) who arrange financing and guarantee that the improvements will generate savings sufficient to pay for the project over the term of the contract. Later enacted in 1998, new legislation created an even easier method to finance capital costs of renewable energy projects. Known as Super ESPCs, these indefinite-delivery, indefinite-quantity (IDIQ) contracts streamlined the process, promising far less time and money to develop a project (EERE, 2007). Figure 15 below depicts DoD's use of ESPC contracts since 1998. No ESPC contracts were awarded in 2004 due to lapse in congressional authority.

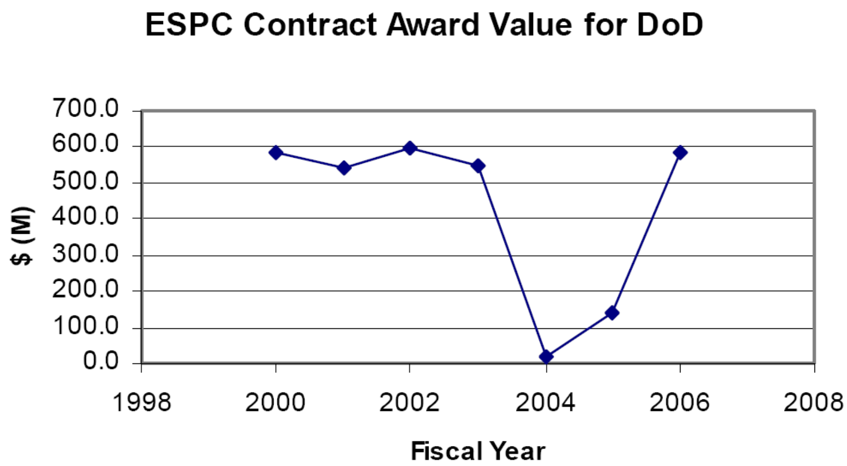

Figure 15. ESPC Contract Award Values for DoD [From: EERE].

Another financing mechanism available to DoD and other Federal agencies is the Utility Energy Services Contract (UESC). UESCs are partnerships with franchised utilities. Under this contract, utility companies typically provide financing to cover capital costs, the utility company is then repaid over the contract term from the energy cost savings (EERE, 2007).

Finally, a funded contract vehicle is available to DoD. The Energy Conservation Investment Program (ECIP) is a subset of the military construction (MILCON) program specifically designated for projects that save money on energy costs. It is an Office of Secretary of Defense (OSD) centrally controlled funding allocation that is released on a case-by-case basis (OSD, 1993).

The fourth important strategy that can strengthen the solar industry and improve its credibility is education and information dissemination. Since it is such a new industry, the need for performance reports and other technological information is paramount. If DoD established a reporting system to independently document electricity produced by solar energy at its bases for sharing with other bases, federal agencies, and private industry, it would likely grow market attention and foster increased learning. The information and lessons learned can be shared with complementary technology developers like turbine and battery manufacturers for instance to educate them on the needs of the field and foster healthy competition. Work in this area can also go a long way in changing the negative image of solar roofs by educating potential adopters about aesthetically pleasing materials and configurations. The DoD annual energy reports to DOE are a fair starting point, but much improvement is needed. There have been inconsistencies from year to year in reporting format, data inclusion, and span of reporting coverage.

A competition that awards cash prizes for best solar powered vehicle or other solar demonstrations would be one particular education and information campaign. The DARPA grand challenges of 2004, 2005 and 2007 for example drew strong competitive spirit from leading universities and research institutions along with substantial media coverage and cash prizes.

D. SUMMARY

The market will not necessarily fund all innovative technologies simply because they are good ideas. Synergies between defense and civil research are vital to assisting the market in diffusing the good ideas. Just as DoD-funded projects like Arpanet, nuclear propulsion and the global positioning system set early standards that gave the commercial sector the framework upon which to create exponential market developments, so too could the early establishment of new energy infrastructure standards (production, transmission, connectivity, and modularity) prove to be the DoD's greatest contribution to America's long term energy strategy.

V. OTHER ISSUES

A. INTRODUCTION

DoD alone will not be able to stave off the impending energy crisis that our nation likely will face in the coming years. As the current price trends increase for oil and other fossil fuel products, it will become more difficult for DoD to operate within its budget. Securing DoD's energy sources should remain a top priority within DoD's leadership. In order to reach a goal of energy independence, DoD should perhaps begin to look at different ways in which they can achieve that goal. Because the acquisition process is a fairly long process, it is recommended that DoD begin to create alliances with emerging solar power companies and universities to conduct research and examine the full potential of solar power for use within DoD.

A strategic alliance is a partnership in which two or more firms combine resources and capabilities with the goal of establishing a mutual competitive advantage (Carpenter & Sanders, 2007). Why should DoD form strategic alliances with companies, universities and possibly other governments who are interested in the benefits of solar power? How can this benefit DoD in the near future and in the long-term? What are the challenges DoD will face in managing this network of alliances? These are important questions to ask because as the energy demand and cost continues to increase and we reach the peak of fossil fuel production, it will be important for DoD to make a thorough analysis of the benefits that solar power can provide. This chapter examines two potential strategies that perhaps, DoD might consider for the successful management of its networking structure and the methods on improving the management of Research and Development. Finally, the challenges that DoD might face if they adopt these strategies are discussed.

B. NETWORKING AND ALLIANCES

1. Introduction

In today's rapidly changing environment, networking can provide a way to enhance product development, increase market share and maintain a competitive advantage over adversaries. Alliances have been frequently used as a strategic instrument because they provide quick and flexible access to external sources (Hoffmann, 2005). The question should be asked is, "Why should DoD form a network of alliances for solar power?" Networks enable forums for discussion, direct attention to new practices and facilitate the transmission of information (Goerzen, 2005). Clearly DoD cannot become a one stop shop for solar power research, development and implementation. Nor should they completely outsource these functions as well. One way DoD might be able to successfully manage the development of solar power is through the process of networking. DoD, in this case will be the "visible hand" that will help guide and nurture this network to bring the best products it can to its end users, the boots on the ground.

2. Strategies for Successful Networking

a. Cluster Building

There are many ways DoD can create and manage an effective network of solar companies and universities. One such way is to create a cluster. A cluster should include supplier firms, university researchers, economic development practitioners, consultants and any other individual or entity form industry, academia or the regional community who have the skills, expertise or resources that are of value to the industry (Carroll, Reid, & Smith, 2007). A benefit from forming a cluster is that synthesizes key actors in industry, the community and academia in order to achieve a well-rounded network (Figure 16).

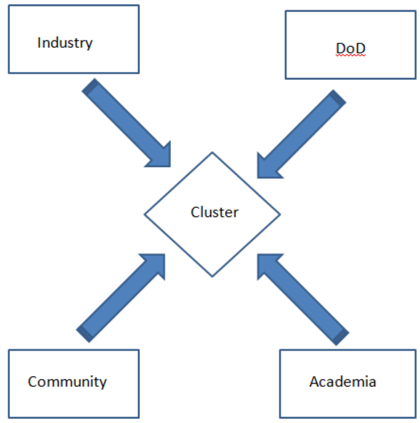

Figure 16. Cluster Partners [After: Reid, Carroll & Smith].

According to Carroll et al., in order for DoD to successfully build a cluster it must meet five key milestones which are comprised of individual steps (Figure 17). The first milestone involves defining the industry, defining the region and inventorying potential cluster members (PCM). A PCM is defined as an individual or an organization that has the potential to contribute to the cluster and who, through that contribution, can provide value to the cluster initiative (Carroll et al., 2007). Defining the industry for DoD is simple: solar power. However, defining the region and potential cluster members maybe a little more difficult for DoD. In all likelihood, it seems reasonable to consider that DoD would choose companies and universities located in the southwest because that is where solar power has the most potential. Once these steps are completed, the next milestone is to conduct three analyses of the supply chain, social network and SWOT respectively. These three analyses provide the base for identifying the key industries, key individuals and the key opportunities and challenges that the DoD would face in forming a solar industry cluster. As Carroll et al. (2007) suggests, a Cluster Strategy Team (CST) would emerge which would compromise roughly between 10-12 people and be a diverse cross-section of academia, industry professionals, DoD personnel and the community. Finally, to complete this process a program manager and champion would be selected. A program manager would supervise the day-to-day operations while the champion would act like a field agent and spend much of their time visiting the actors (Carroll et al., 2007).

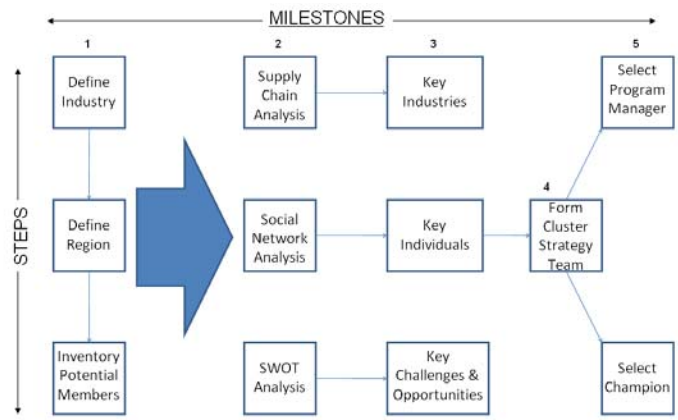

Figure 17. Key Steps in Forming an Industrial Cluster [After: Carroll, Reid, & Smith].

This model suggests that selecting a DoD member as a champion would be the best way for DoD to maintain an overall big picture of the network, and would act as moderator on tough issues that the program manager needed assistance on.

b. Triangular Portfolio Management

Another method that DoD could implement to managing a network of solar power alliances is through using a triangular portfolio management system. As Hoffmann (2005) suggests there are four tasks in which a triangular portfolio management systems is created: portfolio strategy, portfolio monitoring, portfolio co-ordination, and the alliance management system (Figure 18).

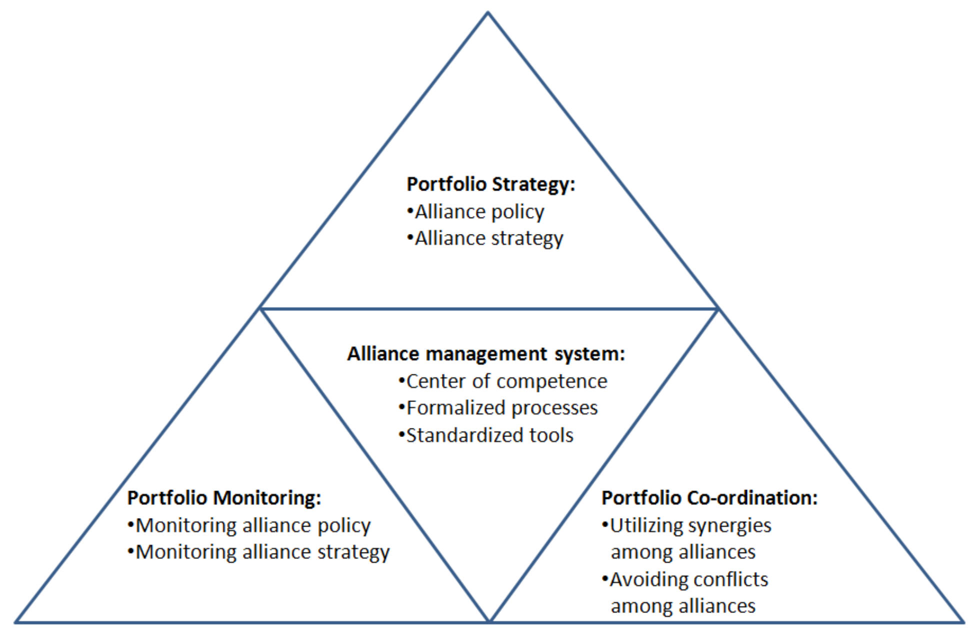

Figure 18. Alliance Portfolio Management [From: Hoffman].

The first thing DoD could do is create the portfolio strategy which is comprised of two underlying core sub-sections: alliance policy and alliance strategy. Alliance policy's objective is to strategically align the alliance activities with the network's strategy and values, while the objective for the alliance policy is to determine the strategic orientation and goals of all alliances of the business unit and the configuration of the business alliance portfolio (Hoffmann, 2005). This is where DoD can dictate how the network for solar power should work, what are the goals it intends to achieve, and how it intends to reach those goals. Creating the portfolio strategy first will help lay the foundation for the rest of the process in creating a successful network.

The second step DoD could perform is to create the portfolio co-ordination. This segment is very important because it will help delineate how DoD will utilize the network's synergy and help avoid potential conflicts within the network. Ideally, DoD should work with potential organizations that have a possibility of being accepted into the network or firms that have signed on to be key instruments in the network's future development and planning. In order for DoD to effectively utilize the synergies in the network, the network itself must be able to transfer information and resources from one firm to another which will allow economies of scope; and mutual specialization allows economies of scale (Hoffmann, 2005).

The third piece of the triangle is portfolio monitoring. The goal of portfolio monitoring is to develop and nurture the performance of the network and allows management (DoD) to intervene if performance fails to live up to the expectations (Hoffmann, 2005). One way DoD could potentially form a monitoring group is to make sure that it represents a cross section of the firms involved, headed by a DoD representative, which could review the network's ability to communicate, work together and achieve the desired goals set forth by the alliance strategy.

Finally, in order to complete the triangular portfolio network, the alliance management systems must be created. The alliance management system provides the infrastructures such as standardized tools and formalized processes as well as specialized roles and positions that support the tasks of managing individual alliances as well as the whole network (Hoffmann, 2005). Here is where DoD might be able to effectively establish the solar network and ensure that it runs efficiently and effectively. By creating a center of competence, establishing formalized processes and generating standardized tools, DoD can ensure the network's success over the long term.

3. R&D: Methods to Forward Their Development

a. Three Pathways to Create R&D Management

R&D costs, as well as the risks have increased significantly in the recent years and as a consequence, more and more firms are collaborating on R&D (Doz, Ring & Olk, 2005). DoD has not escaped this trend. As funding continues to tighten and more scrutiny is placed on controlling costs, DoD will need to be able to live within it's budget. One way DoD can minimize R&D costs is by forming what Doz et al. (2005) call a R&D consortium. According to Doz et al. (2005), there are three critical factors for successful collaboration. These are:

- Presence of a strong sense of the participants' convergent business interests and a feeling of urgency in addressing them prior to their

R&D collaboration, which provides an initial drive and commitment toward building the R&D consortia.

- Pre-existence of social relationships that provide for initial and mutual understanding, which allow the partners to start collaborating more quickly and easily.
- Pre-existence of strategic relationships (which are a function of firm strategies, competitive and market conditions), or at least of a sense of strategic interdependency that may lead to mutual forbearance and a desire to seek common ground.

Doz et al. (2005) then suggests that there are three distinct processes on how R&D consortia form. The first process is the emergent process. This process is one that arises out of a threat[7]. For example, China's military is beginning to emerge as a threat to the United States military. As China continues to grow and build its military, it will proportionally consume more energy resources that will have a potential impact on the United States and its military's ability to meet emerging threats worldwide because of the scare energy resources. To meet this threat, DoD could form a R&D consortia with other countries' defense agencies, such as Japan or Britain's Ministry of Defense, to establish a broad network in solar power/alternative energy resource development.

The second process in which R&D consortia are formed is through an engineering process. This process is usually started by a triggering entity, such as the benefits of collaboration visible to potential partners, helping them along the formation process, securing their various contributions in timely and harmonious fashion and reassuring them about their respective motives (Doz et al., 2005). One way this process would form is if DoD created a new office to develop, manage and execute a strategy for transformation to solar energy. This strategy would act as the triggering mechanism that would simulate interest in solar energy firms and who would want to join the network.

Finally, the third process for forming a R&D consortia is the embedded approach. In the embedded formation process, the potential collaborators already enjoy strong social relationships at the onset of the alliance and have also often built strategic collaboration relationships (Doz et al., 2005). An advantage of this process is that it

[7] Research by Doz et al. (2005) was conducted and their results show an overwhelming trend that this type of process was a direct result of strong competition that could threaten a whole industry.

would take very little management oversight because relationships have already been formed and a network has been established.

The most likely formation of an R&D consortia for DoD would be the emergent approach. Threats to DoD could come in any fashion from the build-up of China's military, to funding cuts from Congress. Just like DoD, the solar companies also face threats in their industry and a joint venture between the two can help stave off any current or future threat.

b. Four Different Ways to Manage R&D

As globalization continues to emerge and rapidly gain steam, DoD will need to be able to meet the challenges of R&D for solar power and should not rule out joint co-operative R&D with foreign countries and businesses. There are many ways for DoD to orchestrate the development of R&D in solar power. According to Zedtwitz and Gassmann (2002), there are four ways that firms can manage their R&D development on an international scale, which are:

- Domestic research and domestic development.
- Dispersed research and domestic development.
- Domestic research and dispersed development.
- Dispersed research and dispersed development.

These four examples offer DoD four different ways to enhance their solar power R&D development on both an international and national level.

Domestic research and domestic development is called the national treasure R&D (Zedtwitz & Gassmann, 2002). Here R&D is kept in house because it is critical to the national security of the United States. On one side, this has potential benefits both economically and politically at home, however on the down side, it offers very little opportunity for DoD to engage with other firms outside of the United States who may have a better technological understanding of solar power development thus stunting growth opportunities. On a more national level, DoD could completely conduct the research and development within its organization. While this would further prevent the likelihood that critical technology would be compromised, it is certain that from a financial standpoint, this complete in-house development and research is not feasible nor in the best interests of DoD.

Dispersed research and domestic development might offer DoD a unique way to tap into the knowledge base of firms that have extensive solar background that are not located in the U.S.. For example, in DoD's solar power network, if there were several companies that were conducting research both in the United States and abroad, if a particular company abroad has a better understanding of solar power technology, the benefit U.S. firms and DoD would enjoy is the knowledge flow from that company into the network. By developing the products back in the U.S., DoD could have a significant effect on the local economy or national economy if a major product development was to take place that could transform the solar power industry.

Domestic research and dispersed development could offer DoD a unique way to utilize U.S. firms and universities in research and also take advantage of low cost development opportunities. The main problem with this approach is that it is a "market driven" model which means that business development is dominated by customer demands and not by scientific exploration (Zedwitz & Glassmann, 2002). But would a "market driven" approach be really that bad? DoD could act as a market driver for solar power by becoming a lead user. From Dew's (2006) article regarding the demand-pull effect with Radio Frequency Identification (RFID), we can see that demand pull, in certain circumstances, can shape the evolution of a technology considerably. If DoD, created enough organized demand for solar power applications and technology requirements, it might just be able to transform the solar energy industry completely. One way DoD might be able to develop this organized demand is through joint ventures with other military organizations from our European allies. In addition, if DoD were the lead buyer, their commitment to the solar industry might help reduce the market risk for companies and could then help to further future development of new solar technologies.

Finally, dispersed research and dispersed development are truly the essence of global organization's commitment to R&D. While this approach maybe the best approach for civilian firms on an international scale, it may not be in the best interest for DoD to fully commit towards a truly global R&D infrastructure, mainly because of the few national security issues that DoD would want to keep secret. On a strictly national level, a network of this structure would be highly beneficial for DoD because it would help reduce costs, improve local economies and create a diverse knowledge flow of information between DoD and its partners.

4. Challenges

DoD will face several challenges by managing this diverse and complex network of solar companies and universities. One such challenge will be to generate a corporate alliance policy, which will bind together these actors in this network. A lack of company-wide rules on when, how and with whom to co-operate can lead to an unbalanced growth of alliances, which can negatively affect the performance of the individual alliances and how these strategies are implemented (Hoffmann, 2005). For example, if there is no written alliance policy, one firm could be seen as getting preferential treatment from DoD, even if DoD's intention was innocent, which could then disrupt the productivity of other firms.

Another challenge for DoD is to effectively manage this complex network and do so with minimal costs to DoD. Goerzen (2005) states that a large and complex alliance network may add to a firm's organizational costs by yielding an expensive, unwieldy and inefficient management structure for several reasons:

- Suitable partners that possess unique resources and capabilities often exist outside of the focal firm's known sphere of contacts which could result in a higher initial search cost due to the difficulty in finding and assimilating information on potential partners.
- Through this process of dealing with unfamiliar entities, the probability of adverse selection would increase and the process by which a firm extracts itself from an unproductive relationship is time-consuming and expensive.
- Once a relationship is established, the new organizational routines would probably require higher monitoring costs given the partner's lack of trust and familiarity with each other's processes.

As DoD builds their network of solar companies and universities another key challenge they face is how each individual firm impacts the other. When a company has a number of alliances, problems in one project can negatively impact other projects, while success, on the other hand, can benefit further joint activities (Hoffmann, 2005). To minimize this conflict of maximize the benefit, the firms should co-ordinate collaborative projects with the same partner (Hoffmann, 2005).

Managing resources effectively will be a key challenge for DoD in the formulation of the network. More specifically, DoD should be careful to protect the vital resources that the network has established and at the same time exploit to the fullest the potential of these resources. In order to do this DoD needs to develop a sense of priority, or orientation, in managing this network (Das & Teng, 1999).

Finally, a R&D challenge that DoD faces is selecting the right pathway to establish a R&D consortia. For example, if DoD has been following the emergent process but a consensus on vision and mission issues has been slow to come. Under these circumstances,, DoD may have to undertake the task of triggering collaboration and begin to employ an engineered process (Doz, et al., 2005).

One key theme throughout the literature was that networks will fail if time, money and energy are not invested properly and with careful analysis on the impact of potential network partners. DoD could help reduce this risk by using a newly formed department, which would be completely responsible for the management, execution and development of this network thus eliminating other constituencies from having to manage the network in an ad-hoc fashion.

5. Summary

Establishing a network with solar power companies and universities is critical for the long-term renewable energy strategy for DoD. There are many different methods on how to manage a network and establish a robust R&D consortia. This report suggests that DoD should actively research different methods and implement the one that fits best. In the process of establishing a network, DoD will face numerous challenges that will test its ability to effectively manage a diverse alliance of firms. These challenges can be overcome by effectively laying out the foundation in conjunction with these firms, establishing good communication flow between entities, and formulating a long term strategy that benefits every actor. By incorporating a newly formed office within DoD for Solar and Renewable Energy, DoD can mitigate the impact of these challenges.

C. MANAGING RISK

1. Introduction

Managing risk is becoming more and more important and challenging as costs, competition, and the complexity of the business environment increase. As companies increase the complexity of their systems, (products, processes, technologies, organizational structures, contracts and so on) they often fail to pay sufficient attention to the introduction and proliferation of loopholes and flaws that increase the risk of involvement in a network (Bonabeau, 2007). It is very important for DoD to understand the consequences of failing to manage risk in the solar environment. Important questions then become: How can DoD manage the risk in the solar industry? What benefits can successfully managing risk bring to DoD? Finally, what guidelines could DoD follow to help minimize the impact of risk management?

2. Managing Risk in Networks

Das and Teng (1999) break down risk into two categories: relational and performance. Relational risk is the risk of unsatisfactory inter-firm cooperation, and performance risk is all other factors that adversely affect network performance (Das & Teng, 1999). In addition, they identify two primary resources that firms can contribute which are: property and knowledge. For example, in the case of a solar power network, firms that are in the solar power industry could be responsible for the property while universities would be responsible for the knowledge background. Both Das and Teng (1999) combined property, knowledge, relational risk and performance risk into a matrix which then produced four distinct strategic orientations (Figure 19).

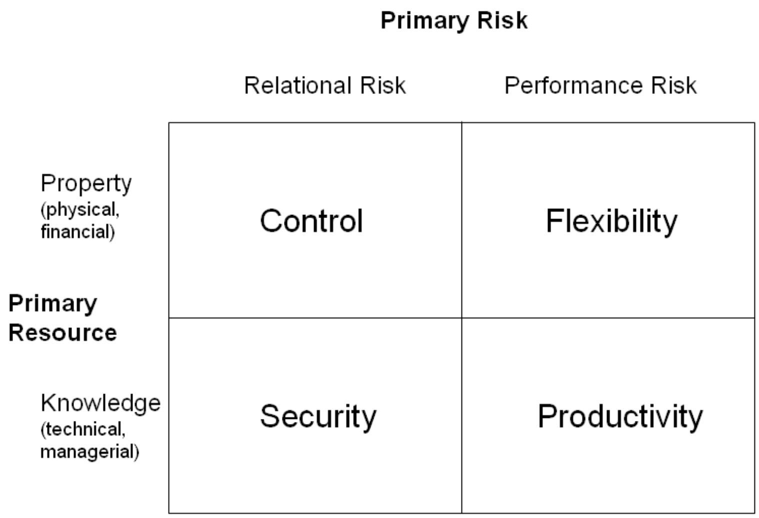

Figure 19. Strategic Alliance/Network Orientations for Primary Risks and Resources [From: Das & Teng].

Control orientation can be achieved by contractual, equity or managerial control. DoD, as the lead player can ensure that companies joining the network can feel comfortable that their properties will not be misused by stating clear and explicit circumstances on when, where and how their assets will be utilized through their network strategy policy. Flexibility orientation offers a firm to be free of rigid, engaging and long-term agreements, enhancing the ability to adapt to changing circumstances (Das & Teng, 1999). The security orientation relates to the fear firms have regarding their technical expertise is stolen from other firms in the network. Even though one of the benefits of forming a network is to share knowledge there must also be a consideration for just how much knowledge sharing will occur, especially if there are competing firms in the same alliance. Here DoD can minimize this impact by outlining limits to the sharing of critical information that could severely impact a firm's technical knowledge advantage. Finally, productivity orientation is when you have combination of performance risk and knowledge as your primary resource. Is the firm able to produce a solid product even though they have the technical resources to do so? In order to mitigate this, DoD can conduct an extensive background investigation on the firm's past performance.

3. Guidelines for Managing Risk

In order to help manage risk in a network, Williams (1996) points out three things firms can do to reduce the level of risk. The first step a firm like DoD can take is to create a process-oriented view of risk management. The second step is to build an effective organizational control structure, and finally the third step is to develop a common business risk language. All of these steps could be incorporated into DoD's solar energy strategy and policy, which would define how each one was going to affect other firms in the network.

Guidelines for managing risk were noted by Das and Teng (1999). They concluded that the managers of the network (DoD) would do very well if they followed these guidelines:

- Emphasize protection of your own primary resource.
- Exercise control through contracts, equity and management.
- Retain flexibility through short-term recurrent contracts, limiting commitment, and effective exit provisions.
- Safeguard continued security by limiting exposure to know-how.
- Ensure increased productivity by emphasizing superior alliance performance.

In addition to those listed above, Jorgensen (2005) noted five key elements of a solid risk management strategy. The first element is to align risk management vision with that of the network. Second, networks should identify and analyze the areas of potential risk to the network. Third, networks should balance their risk objectives by determining how much time, effort and money it will take to achieve these objectives. According to Jorgensen (2005), a risk manager could use a balanced scorecard to clearly articulate these objectives. Fourth, the gaps that develop after establishing the risk management objective should closed with strategic incentives. Here DoD could work with key leaders in the firms to ensure that all risk is minimized as much as possible. Fifth, continual measurement should be taken to constantly monitor the progress of your risk management objectives. If discrepancies arise, then they can be dealt with early on and will minimize their impact on the network.

4. Summary

Risk is inevitable no matter how efficient or productive a network is. The goal is to minimize the risk to the point where it doesn't affect long term goals. DoD can take numerous steps like the examples listed above to ensure that risk is minimized in the solar energy network. As the lead actor in the network, it will be DoD's responsibility to ensure that the firms involved in the network are also contributing to the reduction of risk. By reducing and effectively managing risk, DoD can then utilize the time that would have been spent dealing with risk concerns/issues and instead help guide and nurture the network to achieve its goals.

D. LEGISLATION AFFECTING SOLAR POWER

1. Introduction

As Americans continue to put an emphasis on "going green," the transition from traditional energy sources to renewable sources will continue. Politicians are not exempt from this emphasis and have the responsibility to secure America's energy sources. However, as history shows, politicians flow with the population's attitude. Now, as America faces record high oil prices and current trends show no slowing of the rising costs, America certainly should look towards renewable energy sources. Solar power can secure America's energy source for the future.

2. Energy Tax Incentives for Solar Power

a. Brief History of Energy Tax Incentives Since 1992

The Energy Policy Act of 1992 established a permanent 10 percent business energy tax credit for investments in solar power equipment (Buckner, 2007). In 1998-1999, America saw crude oil prices reach a low of just over $10 per barrel (Congressional Research Service [CRS], 2008). However, after reaching this low point gas and oil prices began to rise. By 2001, Congress was faced with fluctuating oil prices, an electricity crisis in California, and natural gas prices that were spiking because at one point, the spot market prices reached about $30 per million cubic feet (mcf), which was the equivalent of $175 per barrel of oil (CRS, 2008). On March 9th, 2002 the Economic

Security and Recovery Act of 2001 was passed into public law 107-104. This law provided a tax credit for electricity produced from renewable sources and amended the Internal Revenue Code to provide a two-year extension of electricity from renewable resources (Buckner, 2007). The 108th Congress passed some energy tax incentives in the form of the Working Families Tax Relief Act of 2004, which incorporated $146 billion of middle class and business tax breaks (CRS, 2008). The 109th Congress passed substantial legislation in the form of the Energy Policy Act of 2005, which created $2.6 billion for renewable energy incentives such as business tax credits for solar power.

b. Current Tax Issues

On February 27, 2008, an old Energy Tax Provision (H.R. 3221) was reintroduced as a new bill (H.R. 5351) that contained $18.1 billion in renewable energy and energy efficiency incentives. The main effect that this bill will have on solar power is that it will liberalize the 30 percent investment tax credit for business solar and will extend the credit for eight years (CRS, 2008). This should be good news for DoD because it will help incentivize companies to pursue solar power investment, which means that DoD will have a more diverse portfolio of companies to choose from when forming the solar power network. Currently in Congress there are two bills being produced in the House of Representatives (H.R. 5984) and Senate (S. 2821) that will form the Clean Energy Tax Stimulus of 2008 and extend the tax credits for solar investment until 2017.

3. Recent and Pending Laws Affecting Solar Power

The Solar Energy Research and Advancement Act of 2007 (H.R. 2774) was incorporated into the Energy Independence and Security Act which was signed into law on December 19th, 2007. This law provided funding for research in thermal energy storage, studies on solar power integration into the electrical grid, a grant program that will help strengthen the solar industry workforce through training and internship programs and photovoltaic demonstration program in which grants will be given to states to demonstrate advanced photovoltaic technology (Library of Congress, 2008).

Another piece of legislation being considered is the New Direction for Energy Independency, National Security and Consumer Protection Act. For solar power, this act establishes pilot programs for the development of strategic solar reserves on federal land. Currently this legislation was referred to the House Ways and Means Committee and is pending further review.

E. SUMMARY

There are multiple ways DoD might manage the solar power network. Forming a cluster or using a triangular approach are just two of them. As DoD develops this complex network, it will face several challenges that will threaten the network's ability to produce quality products. If DoD does not actively engage these threats head on, the entire network could collapse. To ensure that these challenges are met, DoD might consider investing the time, money and effort into establishing sound policies, strategies and organizational structure to the network.

As in any organization, DoD should effectively manage the risk of creating a complex network of companies and universities. The use of various methodologies will work and it will be DoD's responsibility to find the right one that fits best within the network. Only active management from DoD can help ensure that the risk in minimized to an acceptable level.

Finally, new legislation is being considered to make solar power a more attractive alternative to traditional energy sources. These incentives will create opportunities for companies involved with solar power to more actively engage in research, production and investment in solar power. DoD can capitalize on this trend which will create a long term benefit for both DoD and the network in which it resides.

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VI. CONCLUSION

A. INTRODUCTION

> In the mid to late 1970s, America faced an oil crisis. The federal government acknowledged that there must be a plan of action to transition to other energy sources:
>
> Because we are now running out of gas and oil, we must prepare quickly for a third change, to strict conservation and to the use of coal and permanent renewable energy sources, like solar power.
>
> JIMMY CARTER, televised speech, April 18, 1977

Unfortunately, this transition was short lived and the U.S. quickly got away from making the complete transformation to renewable energies as oil prices came down and the energy crisis dissolved. Thirty-one years later, the U.S. is faced with another oil crisis and this time it shows no signs of improvement. The current oil crisis we now face is threatening DoD's ability to operate and is also having a significant impact in the U.S. economy. However, this scenario is different and offers DoD a unique opportunity to capitalize on this current crisis. What is significantly different is the environmentalism movement that has taken root and has now become an important part of U.S. companies to re-think how they do business in order to preserve the environment. DoD can now position themselves to become the leader in the transformation from fossil fuels to renewable energy.

B. CLOSING REMARKS

1. Solar Power: A Secure, Reliable and Cost Competitive Energy Source

After thorough analysis, we have concluded that while solar power is still not the overall most cost effective and efficient energy source for DoD on a large scale, it can be quite cost effective in certain niches. As a result, solar power can become an important addition to DoD's diverse renewable energy portfolio. In addition, as costs for solar power continue to decrease and its efficiency continues to improve, solar power may make its case for further expansion into larger projects and encompass a wide range of applications within DoD. Finally, solar power is a secure and reliable energy source that can help provide DoD with its energy requirements for the future.

2. Networking Offers DoD a Way to Exploit Solar Power

DoD can help the advancement of solar power research, development, and the management of future military requirements by establishing a network of companies and universities that will interact with DoD and produce top grade solar products for the military. There are many ways to develop a network, but DoD should give careful consideration in choosing the one that fits best. This careful analysis on which network is the one that fits best will help reduce the challenges that DoD will face when establishing the newly formed network. In addition, by selecting the right network DoD might be able to help reduce and effectively manage the risk both it and the other firms will assume in this process.

3. DoD Can Play a Role in Driving Diffusion and Innovation

If DoD is going to drive diffusion, it must comprehend the sources and effects of innovation uncertainty. The three areas in which DoD should focus its knowledge on uncertainty are: potential uses; complimentary innovations; and the value and economic feasibility. Each one must be carefully analyzed by DoD, so that it can be ready to make careful decisions. There are several different ways to drive diffusion, but generally speaking, they can be categorized as demand-pull or supply-push activities. DoD's unique purchasing power, financing opportunities, and contracting channels could be a strong catalyst for driving the development of niche solar applications up the diffusion curve to mainstream status.

C. RECOMMENDATIONS

This report proposes recommendations for DoD to undertake in order to ready itself for the transformation away from fossil fuels:

- Create an office under the Secretary of Defense to facilitate the development, management, and execution of the transformation to renewable energy.

- Prepare the acquisition community for the transformation from fossil fuels to solar power and other renewables. Until the creation of the new department, the Under Secretary of Defense (Acquisition, Technology and Logistics) will be acting as the lead office in handling the transformation and should play a major role in assisting with this transformation.
- Establish a reporting system to independently document electricity produced by solar energy at its bases for sharing with other bases, federal agencies, and private industry. This would have to improve upon the current annual energy reports and have the potential to help facilitate market attention and foster increased learning.

D. AREAS FOR FURTHER RESEARCH

1. Performance Measurement

There are many ways in which firms can measure network performance. Which one best fits the DoD network for solar power? How would DoD and the associated firms respond to this analysis if it is negative? What are management options DoD could undertake to offset any negative trends?

2. Solar Technology Ready for the Field

While this paper took more of a strategic look into how DoD could influence and manage the transition to solar power one thing that was not covered was exactly what solar products, already in existence, could have an immediate impact on DoD's operational capabilities?

3. Political Impact of Lobbying for Solar Power

How could DoD influence the transformation to solar energy through lobbying Congress? What roadblocks would DoD face? Are there any legal implications or ethics considerations DoD must consider? What strategy could DoD take to leverage Congress in creating new laws that favor renewable energy over fossil fuels?

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